LMSC D764514

SATELLITE SERVICES SYSTEM ANALYSIS STUDY

NASA-CR-16105

FINAL REPORT
PART II VOLUME 2

STUDY RESULTS

CONTRACT NAS 9-16121

DRL ITEM NO. MA-834T
LINE NO. 4

22 JULY 1981

(NASA-CR-161050-Vol-2-Pt-2) SATELLITE SERVICES SYSTEM ANALYSIS STUDY. VOLUME 2, PART 2: STUDY RESULTS Final Report (Lockheed Missiles and Space Co.) 49 p HC A03/MF A01 CSCL 22A G3/16 N81-32178 Unclas 35040

NASA JOHNSON SPACE CENTER

LOCKHEED MISSILES & SPACE COMPANY, INC. SUNNYVALE, CALIFORNIA

LMSC-D764514

SATELLITE SERVICES SYSTEM ANALYSIS STUDY

FINAL REVIEW
PART II

PRESENTED BY
LOCKHEED MISSILES & SPACE COMPANY, INC.
SUNNYVALE, CALIFORNIA

TO

NASA JOHNSON SPACE CENTER
HOUSTON, TEXAS

CONTRACT NAS 9-16121
DRL ITEM NO. 4,DRD NO. MA-834T
22 JULY 1981

FOREWORD

This document contains the detailed final results of the Satellite Services System Analysis Study Part II performed for NASA Johnson Space Center by Lockheed Missiles & Space Co., Inc. It is submitted, together with the Executive Summary, Volume I in fulfilment of the requirements (DRL Items MA-834T and MA-745T) of Contract NAS 9-16121, which was initiated on 1 August 1980.

This volume includes a summary of the Part I study results which were previously documented in February 1981.

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Satellite Services System

Study Results, Part II

1 - SUMMARY OF PART I
2 - SERVICE EQUIPMENT PRELIMINARY DESIGN
3 - PROGRAM PLANS
4 - SYSTEM COST ESTIMATE
5 - CONCLUSIONS

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ACRONYMS USED IN THE STUDY

1.	CR&R	CHANGEOUT, RECONFIGURE OR RESUPPLY - A GENERIC MISSION GROUP
2.	DARPA	DEFENSE ADVANCED RESEARCH PROJECT AGENCY
3.	DMP	DEPLOYMENT AND MAINTENANCE PLATFORM = HANDLING AND POSITIONING AID + PIDA
4.	DOF	DEGREES OF FREEDOM
5.	DoD	DEPARTMENT OF DEFENSE
6.	DSCS	DEFENSE SATELLITE COMMUNICATIONS SYSTEM
7.	EMC	ELECTROMAGNETIC COMPATIBILITY
8.	ETR	EASTERN TEST RANGE = KENNEDY SPACEFLIGHT CENTER
9.	EVA	EXTRAVEHICULAR ACTIVITY
10.	GFE	GOVERNMENT FURNISHED EQUIPMENT
11.	GEO	GEOSYNCHRONOUS ORBIT
12.	GSE	GROUND SUPPORT EQUIPMENT
13.	HEO	HIGH ENERGY ORBIT
14.	I/F	INTERFACE
15.	IFWG	INTERFACE WORKING GROUP
16.	IOC	INITIAL OPERATING CAPABILITY
17.	IVA	INTRAVEHICULAR ACTIVITY
18.	LEO	LOW EARTH ORBIT
19.	MTV	MANEUVERABLE TV FLYER
20.	ORV	ORBIT REPLACEABLE UNIT
21.	OTV	ORBIT TRANSFER VEHICLES
22.	POCC	PROGRAM OFFICE OPERATIONS CENTER
23.	RMS	REMOTE MANIPULATOR SYSTEM
24.	S^3	SATELLITE SERVICES SYSTEM
25.	SCF	SATELLITE CONTROL FACILITY (USAF)
26.	SOC	SPACE OPERATIONS CENTER
27.	SSO	SATELLITE SERVICING ORGANIZATION (JOHNSON SPACE CENTER)
28.	SSOCC	SATELLITE SERVICES OPERATIONS CONTROL CENTER
29.	STC	SATELLITE TEST CENTER (USAF)
30.	STDN	SPACE TRACKING AND DATA NETWORK (NASA)
31.	STE	SYSTEM TEST EQUIPMENT
32.	TMS	TELEOPERATOR MANEUVERING SYSTEM
33.	WBS	WORK BREAKDOWN STRUCTURE

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1. Summary of Part I

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STUDY OBJECTIVES

The Study Objectives are presented in order to orient the reader and to set the stage for the remainder of this presentation.

Satellite Services System Analysis
Study Objectives

PART I

- DEFINITION OF SATELLITE USER MARKET
- ANALYSIS AND DEVELOPMENT OF DESIGN REFERENCE MISSIONS
- DEFINITION OF SATELLITE SERVICES CONCEPT AND SCHEDULE BASED ON DESIGN REFERENCE MISSIONS
- SCOPING OF FULL SATELLITE SERVICE SYSTEM PROGRAM RESOURCES

PART II

- PERFORMANCE OF PRELIMINARY DESIGN OF NEW AND MODIFIED SERVICE EQUIPMENT
- PREPARATION OF PROGRAM AND OPERATIONS PLAN
- DEVELOPMENT OF RESOURCES REQUIREMENTS

STUDY METHODOLOGY

This chart shows an overview of the tasks which made up the Satellite Services System Analysis Study and their progression.

The early mission model was developed through a survey of the potential user market which included NASA, DoD, commercial and international space ventures. Service functions were defined and a group of design reference missions were selected which represented needs for each of the service functions. Servicing concepts were developed through mission analysis and STS timeline constraint analysis.

The hardware needs for accomplishing the service functions were identified with emphasis being placed on applying equipment in the current NASA inventory and that in advanced stages of planning.

A more comprehensive service model was developed based on the NASA and DoD mission models segregated by mission class. The number of service events of each class were estimated based on average revisit and service assumptions.

Service Kits were defined as collections of equipment applicable to performing one or more service functions. Preliminary design was carried out on a selected set of hardware needed for early service missions.

The organization and costing of the satellite service systems were addressed in the program planning subtasks.

Study Methodology

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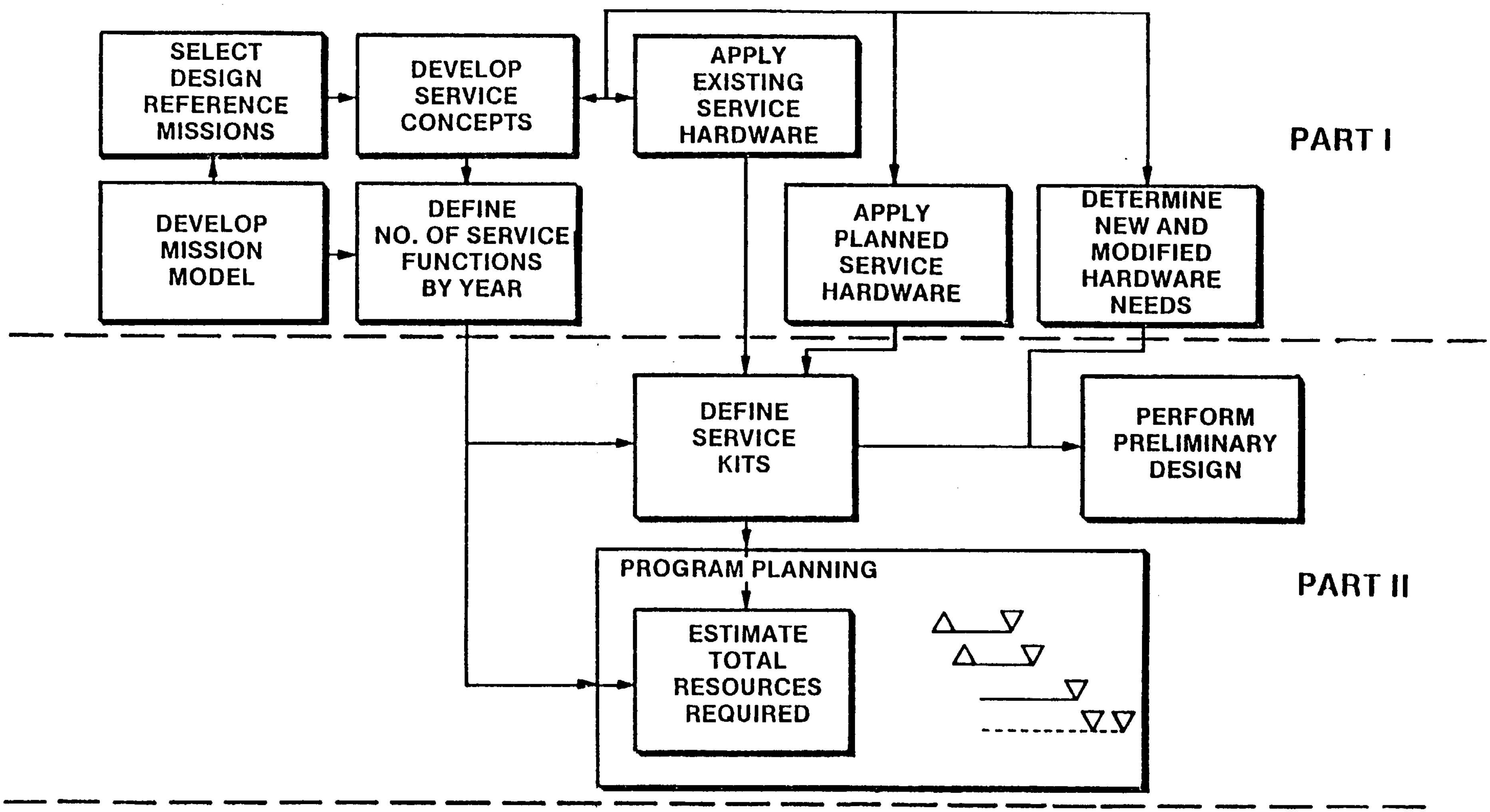


LOCATION OF PLANNED SATELLITES

AVERAGE ALTITUDE DISTRIBUTION

This histogram and those that follow characterizes the LMSC S^3 data base. The listings of planned missions is not exhaustive because most synchronous and planetary probe missions were deliberately excluded. Only a sample of these mission types were included to represent the "deployment only" classification. The average altitude distribution is plotted in this figure. The DoD missions altitude profile is markedly different from the NASA/commercial/foreign missions. The DoD altitude distribution indicates that the preponderance of the satellites are higher than the Orbiter capability and will require propulsion (and guidance) to rendezvous with the Orbiter for servicing.

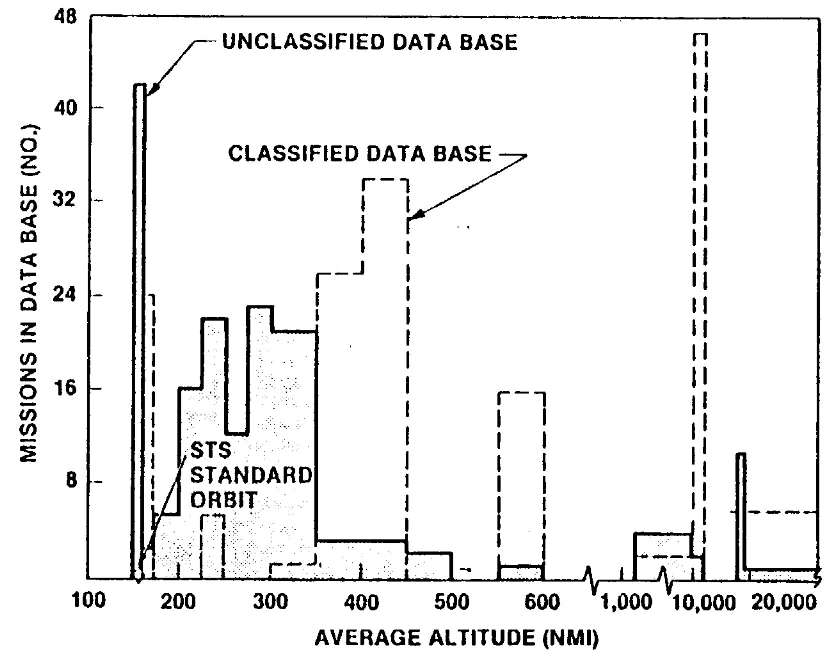
Data entered into the data base was drawn primarily from:

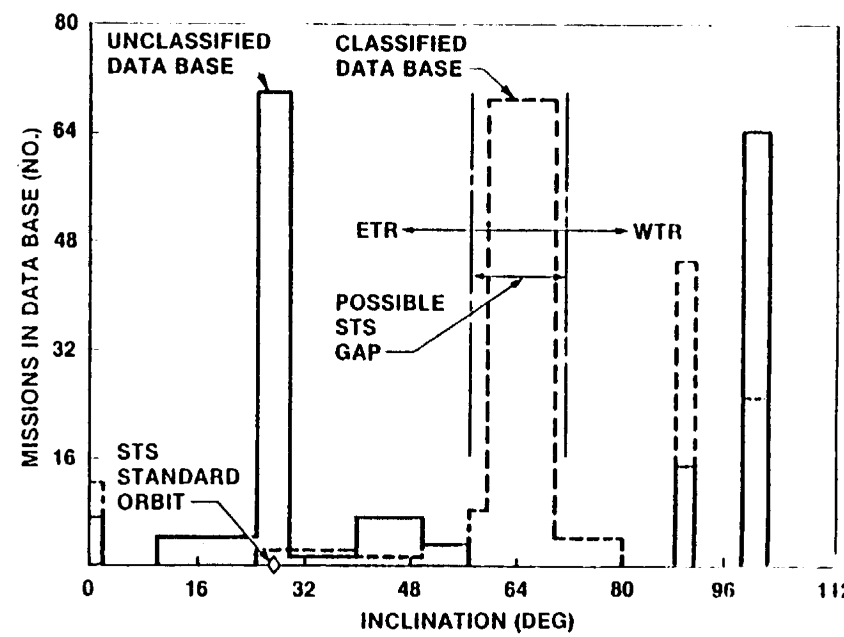
- NASA STS Mission Model - 1977
- STS Flight Assignment Baseline - Sept 1980
- DoD STS Utilization Plan - May 1980
- Random Sample of Norad Space Objects Identification Summary

INCLINATION DISTRIBUTION

This figure illustrates the difference in inclination distribution between the NASA/commercial and the DoD missions. The lack of a large number at very low inclinations is due to the deliberate exclusion of synchronous-equatorial missions except for a few representatives for the "deployment only" mission classification.

Location of Planned Satellites





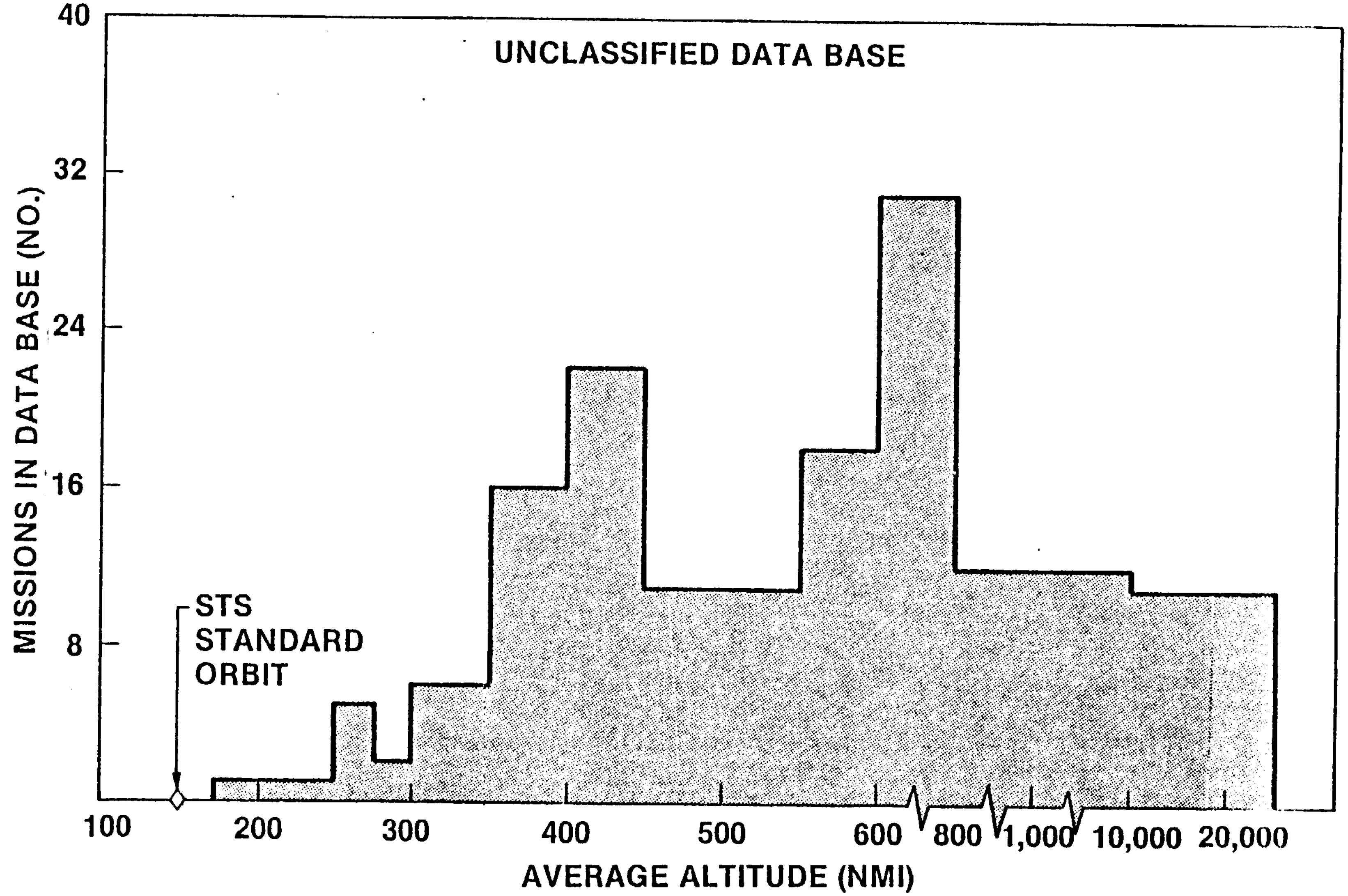
SPACE DEBRIS AND OPERATIONAL SATELLITE ALTITUDE DISTRIBUTION

The space debris and operational satellite data entered into the SSS data base was derived primarily from an unclassified random sample of the Norad Space Objects Identifications Summary provided by JSC. No classified data was entered. The curve can only be considered as a rough indication of the distribution of 11,000 pieces of space objects in the Norad Listing. The lack of low altitude population probably is caused by the rapid decay of satellites in these orbits. No distinction is drawn between existing operational and dead satellites because most currently operational satellites will become space debris in the 1983-1993 study timeframe. This sample indicates the potential for garbage disposal missions.

Conclusions drawn are:

- The recovery/disposal of space debris will in general require the use of some form of orbital transfer vehicle; or
- Debris removal must wait until the orbits decay to the STS standard orbits.

Space Debris and Operational Satellite Distribution



MISSION CLASSES VS SERVICE FUNCTIONS

This figure cross-correlates the service need functions and the classes of missions. Each "X" indicates a potential service function for that class of satellite. Not all functions are applicable to a specific member of the satellite class, but it is evident that the free flyers are subject to the widest potential for servicing.

Mission Classes vs Service Functions

SERVICE FUNCTIONS / MISSION CLASSES	FREE FLYER STS INACCESSIBLE	STS ACCESSIBLE FREE FLYER	FREE FLYER DEBRIS	DEPLOY ONLY	SORTIE
DEPLOY	X	X		X	
RETRIEVE					
• STOW			X		
• BERTH/DOCK	X	X			
OBSERVE	X	X	X	X	X
SUPPORT					
• CHANGEOUT	X	X			X
• REPAIR	X	X		X	X
• RECONFIGURATION	X				X
• RESUPPLY	X	X			X
EARTH RETURN					
• DEORBIT	X	X	X	X	
• DEBRIS COLLECTION			X		
• ORBITER/SATELLITE RETURN	X	X	X	X	X

DESIGN REFERENCE MISSIONS VS SERVICE FUNCTIONS

This table illustrates the procedure used to narrow the choice of Design Reference Missions. Each candidate was evaluated for service functions that are required or useful for the mission. The candidates shown here are the Design Reference Missions which were ultimately selected. The selected set requires the full complement of service functions.

Design Reference Missions vs Service Functions

SERVICE FUNCTIONS / DESIGN REFERENCE MISSIONS	SPACE TELESCOPE	SOLAR MAX	OAO-3	NOSS	COBE	GALILEO
• DEPLOY	X			X	X	X
• RETRIEVE						
— STOW		X	X	X		
— BERTH/DOCK	X			X		
• OBSERVE	X	X	X	X	X	X
• SUPPORT						
— CHANGEOUT	X					
— REPAIR	X	X		X	X	X
— RECONFIGURATION	X				X	
— RESUPPLY				X	X	
• EARTH RETURN						
— DEORBIT			X			
— DEBRIS COLLECT.			X			
— ORBITER RETURN	X		X	X		X

CANDIDATE NEW EQUIPMENT FOR PRELIMINARY DESIGN (PART II)

The eight categories of new equipment are presented here. Items selected for preliminary design in Part II of the study are indicated. The results of the design effort are given in Section 2 of this report.

Candidate New Equipment for Preliminary Design (Part II)

SAFETY EQUIPMENT	SERVICE EQUIPMENT — ORBITER MOUNTED	CREW PROTECTION AND AUGMENTATION EQUIPMENT	SATELLITE AND DEBRIS CAPTURE HARDWARE
PORTABLE GROUND. STRAP* SAFEING KIT/TOOLS SHARP CORNER/EDGE PAD KIT*	SATELLITE EXTRACT/ INSERT PIVOT/ROTATE TABLE* UMBILICAL MATE/DEMATE*	NONE	ORBIT ATTACH/REMOVE GRAPPLE FIXTURE* GRAPPLE ASSEMBLY STANDOFF FIXTURE* DEBRIS COLLECTION CONTAINER

SERVICE EQUIPMENT — GENERAL	WORK SYSTEMS/AIDS	HAND TOOL EQUIPMENT	MANEUVER/ STABILIZE AND RETRIEVAL HARDWARE
GAS/LIQUID EVA CONNECTOR GAS/LIQUID MANIFOLD	PORTABLE FOOT RESTRAINT * STOWAGE CONTAINER RACK/TIE-DOWN PLATFORM* MANEUVERABLE TV	RTV COATING APPLICATOR* ENERGIZED DRILL	EXTENDABLE/ ARTICULABLE BOOM

*SELECTED FOR PRELIMINARY DESIGN

PAYLOADS OF OPPORTUNITY

The term "payloads of opportunity" is used in the NASA Flight Assignment Baseline but not defined. It means the identified excess capability in payload weight and length for a given STS flight.

The data presented here shows the complete set of opportunity payloads for both NASA and DoD flights. Every STS flight having either weight or length available was listed. This results in showing some payloads with zero length but finite weight and vice versa.

The flights are grouped by year and inclination. The individual altitudes are the STS low altitude standard orbit. For purposes of rendezvous servicing, the orbit would be modified to match that of the target satellite. Rendezvous timing requirements could preclude effective use of a given flight if the primary mission has critical launch window constraints.

The flight assignment baseline is truncated in 1985 but the opportunities for carrying ancillary payloads will grow with expanding STS use.

The median weight provided for the non-zero payloads of opportunity, based on a log normal distribution, is 5100 lb.

Payloads of Opportunity

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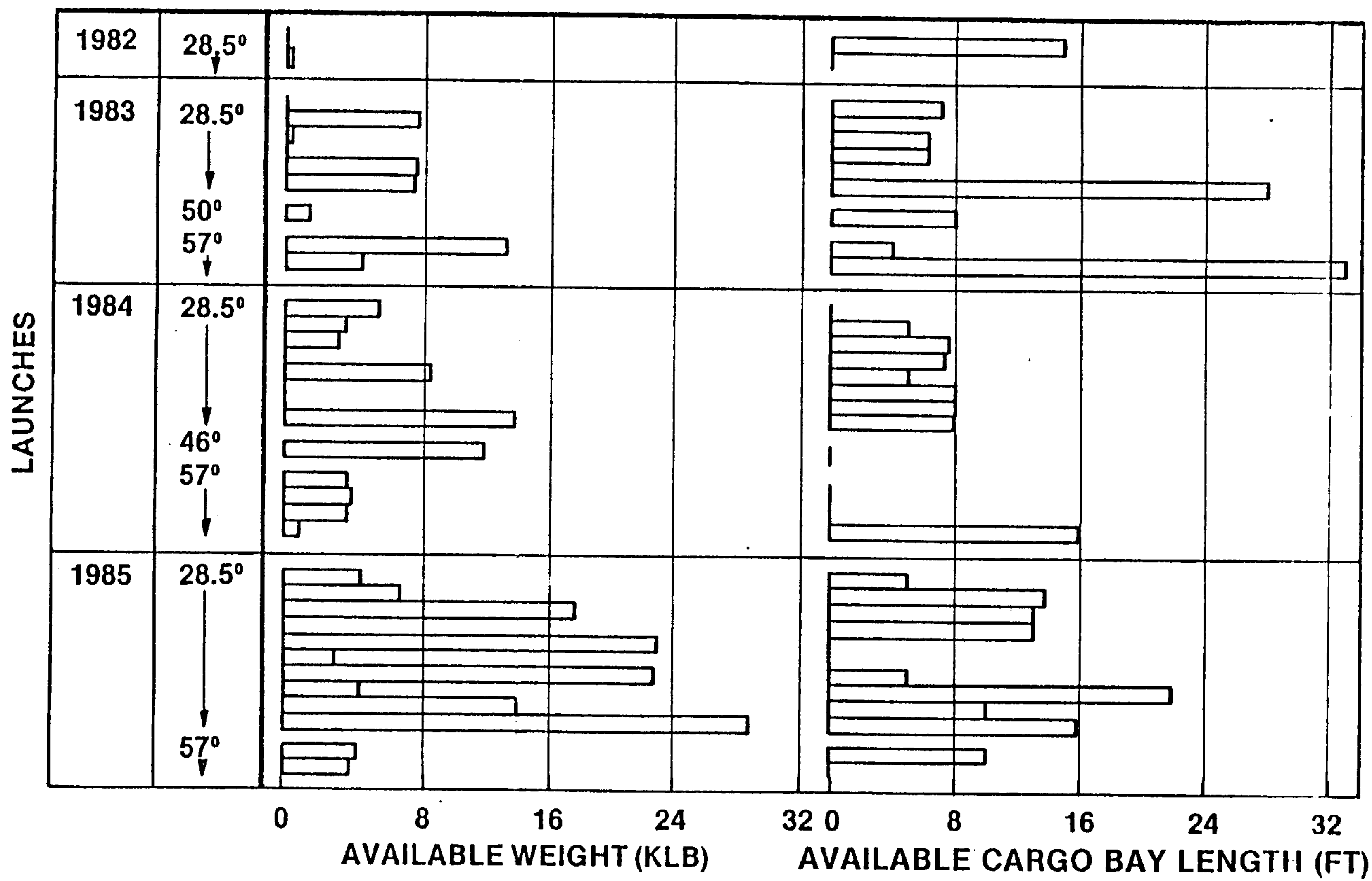

PRINCIPAL ACCOMPLISHMENTS

PART I

The accomplishments of Part I of the Satellite Services System Analysis Study have been a logical and traceable progression from the definition of the satellite user market and the selection of the design reference missions to the definition of a comprehensive set of satellite service functions and the identification of service equipments (existing, modified, new) and their first cut cost estimates.

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Principal Accomplishments

Part I

- DEVELOPED SATELLITE USER DATA BASE AND MANAGEMENT COMPUTER PROGRAM
- IDENTIFIED SATELLITE SERVICE FUNCTIONS FOR 1983-93 TIME FRAME
- SELECTED SEVEN DESIGN REFERENCE MISSIONS WHICH ENCOMPASS ALL IDENTIFIED SERVICE FUNCTIONS
- DEFINED REFERENCE SERVICE MISSION FOR TIME LINE AND FIRST CUT COST ESTIMATES
- IDENTIFIED PROBLEMS AND DEVELOPED CONCEPTUAL APPROACHES FOR SATELLITE DEBRIS COLLECTION AND EARTH RETURN
- IDENTIFIED REPRESENTATIVE SATELLITE SERVICE HARDWARE FOR 1983-93 TIME FRAME
- ESTABLISHED NEED AND DEFINED 13 MODIFICATIONS TO NASA EXISTING AND PLANNED EQUIPMENT
- ESTABLISHED NEED AND DEFINED 85 NEW SERVICE EQUIPMENT FOR 1983-93 TIME FRAME
- ESTABLISHED FIRST CUT COST ESTIMATES FOR CANDIDATE SERVICE EQUIPMENT

CONCLUSIONS

The principal conclusions of Part I of the study are summarized. Requirement for a ΔV capability above and beyond the current STS capability is of prime importance for the development of an effective satellite services system. Of equal importance is the need to design future satellites for on-orbit servicing.

The fact that the current NASA inventory of a space qualified equipment can be used by the astronauts in performing an extended variety of service functions is a tribute to the advanced planning and the capability of man-in-space. No large expenditures are required to establish an organized satellite service system.

Conclusions (1 of 2)

- FUTURE SPACE MISSIONS SHOULD BE DESIGNED FOR ON-ORBIT SERVICING
  - STANDARDIZATION OF SERVICING DOCUMENTATION
  - END-TO-END SYSTEM INTERFACE MANAGEMENT

    THESE FACTORS WILL MINIMIZE:
    - SYSTEM INTEGRATION
    - CREW TRAINING
    - DEVELOPMENT PLANNING
    -
    -
- THE CAPABILITY FOR SATELLITE SERVICING EXISTS TODAY
  - EXPANDED CAPABILITY CAN BE DEVELOPED AS STS USAGE INCREASES
  - PROJECTED SATELLITE SERVICE COST BENEFITS RANGE FROM 0.6 TO 1.4 $B/YEAR BY 1990

Conclusions (2 of 2)

- THE MAJORITY OF PLANNED FUTURE MISSIONS WITH THE POTENTIAL FOR IN-ORBIT SERVICE REQUIRES ORBIT TRANSFER CAPABILITY FROM STS STANDARD ORBIT TO OPERATIONAL ORBIT – EITHER SELF-CONTAINED OR BY SEPARATE VEHICLE

- THE ELEMENTS INVOLVED IN A SATELLITE DESIGN-FOR-SERVICE DECISION INCLUDE:
  - SATELLITE DESIGN COST ASSOCIATED WITH RENDEZVOUS, MODULARITY, ASTRONAUT CONTACT
  - SIMULATION OF SERVICE FUNCTIONS (0 G)
  - ASTRONAUT FAMILIARIZATION AND TRAINING
  - REDUCTION OF REDUNDANCY
  - EXTENSION OF MISSION LIFE
  - COST OF SERVICE VS. REPLACEMENT (SHARED VS. DEDICATED FLIGHT)

NASA

2. Service Equipment Preliminary Design

- MODIFIED GRAPPLE FIXTURE
- GRAPPLE FIXTURE ATTACH OPTIONS
- PORTABLE FOOT RESTRAINT
- PORTABLE GROUNDING STRAP
- MATE/DEMATE UMBILICAL
- SHARP CORNER/EDGE PADDING
- PROTRUBERANCE COATING APPLICATOR
- SHARP CORNER/EDGE PAD KIT
- DEPLOYMENT AND MAINTENANCE PLATFORM
- CARGO BAY RACK/TIE-DOWN PLATFORM

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MODIFIED GRAPPLE FIXTURE

PURPOSE: The existing RMS Grapple Fixture is designed for permanent emplacement on satellites destined for launch/recovery by the orbiter. For the purpose of giving the device portability and universality of application (e.g., for use in recovery of satellites and space debris without a pre-launch installed grapple), a design modification is presented consisting of a stand-off adapter provided with and end fitting or attachment lug suitable for use with a variety of spacecraft attachment devices. (The attachment fixture is presented in the next Figure.)

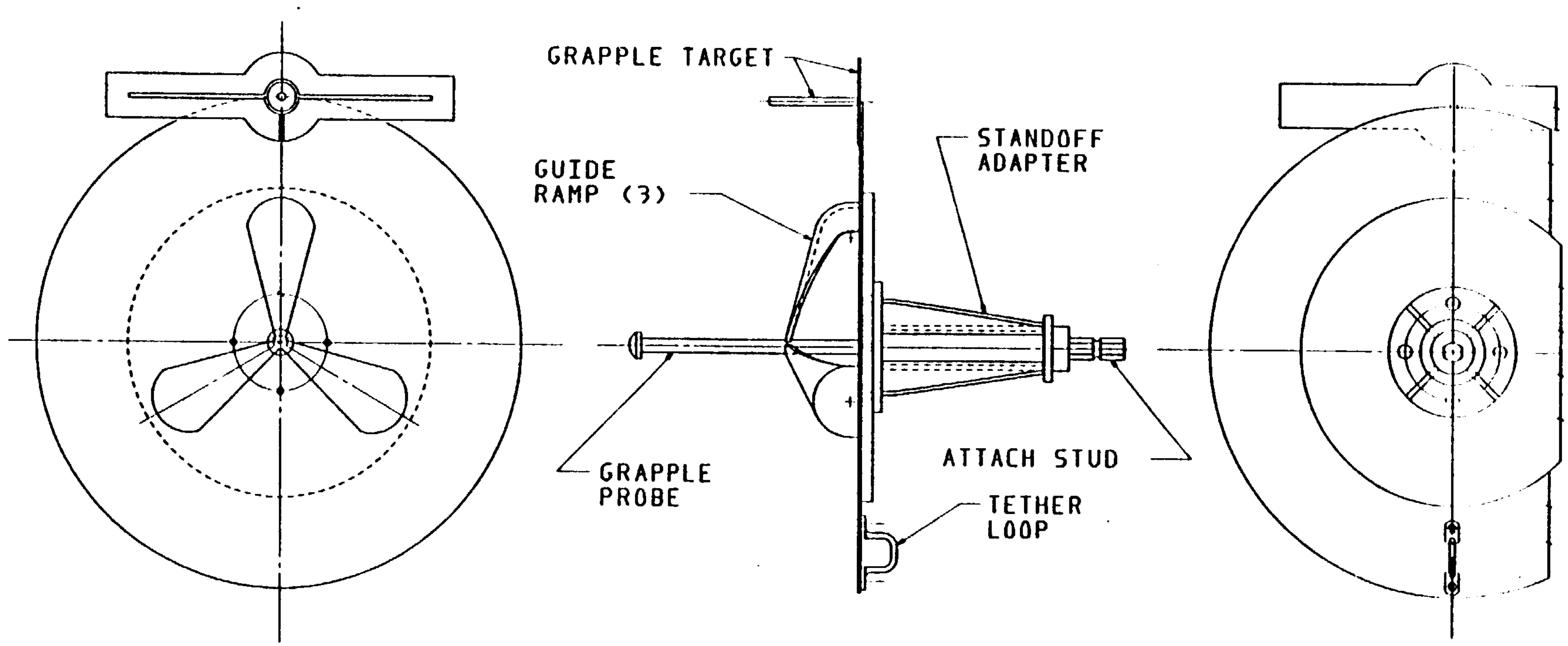
REQUIREMENTS:

- Design Loads - Launch/Landing as stowed
  - Orbit, sustain all RMS load capabilities
- Interface with standard female receptacle on S/C attachments
- Crew transportable
- Size: 292 mm (11.5 in) x 150 mm (5.9 in)
- Mass (with (S/C attach) - 8.39 Kg (18.5 lb)

OPERATIONS: A portable, modified grapple fixture is provided in each recovery tool kit together with a number of S/C attachment devices. After an initial survey of the object being retrieved, the most suitable S/C attachment device is withdrawn from tool kit and affixed to the attachment stud of the grapple fixture by means of a mating, female receptacle and a locking, or "Pip" pin. The assembled device is then carried to and attached upon the recovery object by the EVA crew. A loop is provided for transportation by belt tether. Hand carry and manipulation capability is provided by gripping the grapple probe rod.

APPLICATIONS: The Modified Grapple Fixture is potentially included in the Earth return, Deorbit, and Spin Service Kits.

Modified Grapple Fixture and Target



GRAPPLE FIXTURE ATTACH OPTIONS

PURPOSE: The total Portable RMS Grapple is made up of two elements: (1) a standard RMS grapple fixture modified by a stand-off adapter and male attachment stud, shown on the previous chart; and (2) a spacecraft interface device made up of an attachment mechanism and a female receptacle suitable for mating with the male stud on the modified grapple fixture. The stud and receptacle hole are of hexagonal design for the transmission of RMS torsional inputs.

Three typical spacecraft attachment options are shown; a bonding pad system for attachment to satellites which have flat or large radius-of-curvature surfaces, a strap-on device for attachment to intermediate sized spacecraft members, and a clamping or "Ice-Tong" device for attachment to two relatively small, parallel members.

It should be noted that the use of a detachable "female receptacle" for the grapple spacecraft interface permits a much wider variety of spacecraft attachment schemes than are shown. In scheduled recovery missions, these devices can be tailored to conform exactly to target spacecraft design peculiarities.

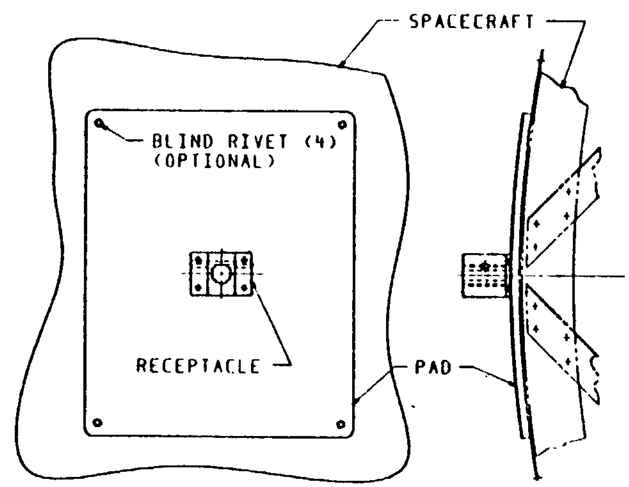
REQUIREMENTS:

- Design Loads - Launch/Landing as stowed
  - Orbit, sustain all RMS load capabilities
- Interface with standard male attachment stud or grapple adapter
- Size (Max), 510 mm (20 inc) on all three dimensions
- Weight - not to exceed 8.39 Kg in combination with modified grapple fixture

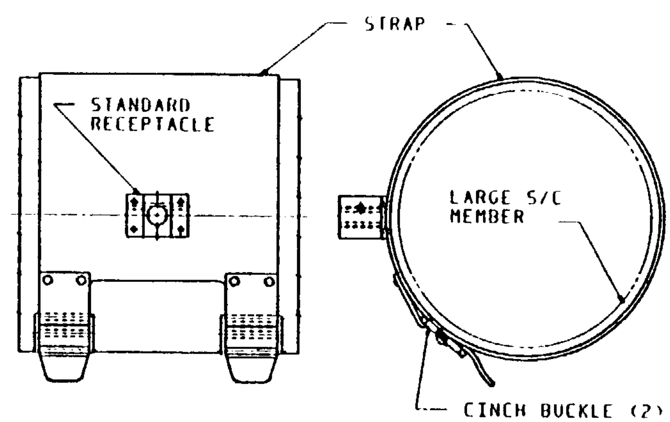
OPERATION: See Modified Grapple Fixture description.

APPLICATION: As with the modified grapple fixture the spacecraft attach options are candidates for use in the Earth REturn, Reorbit, and Spin Service Kits.

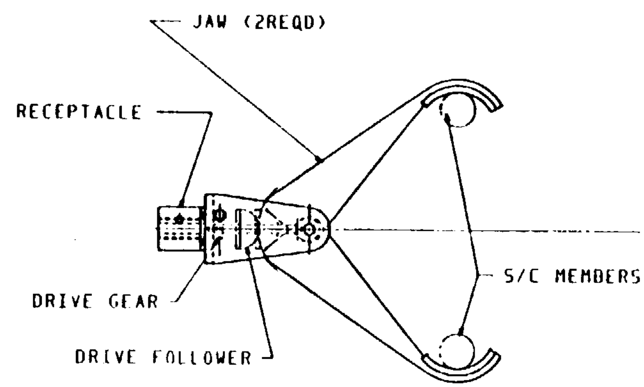
Grapple Fixture Attach Options



FLEXIBLE BONDING PAD



STRAP-ON ATTACHMENT



ICE-TONG ATTACHMENT

PORTABLE FOOT RESTRAINT

PURPOSE: In its present application, the standard foot restraint is used as a fixed installation in larger systems and its use is limited in terms of both location and orientation. In order to provide for much wider application as well as versatility, the design has been extensively modified. Shown here is the design for application on the Space Telescope as well as other satellites where portability and articulation are advantageous.

REQUIREMENTS: The portable foot restraint shall comply with and conform to these requirements:

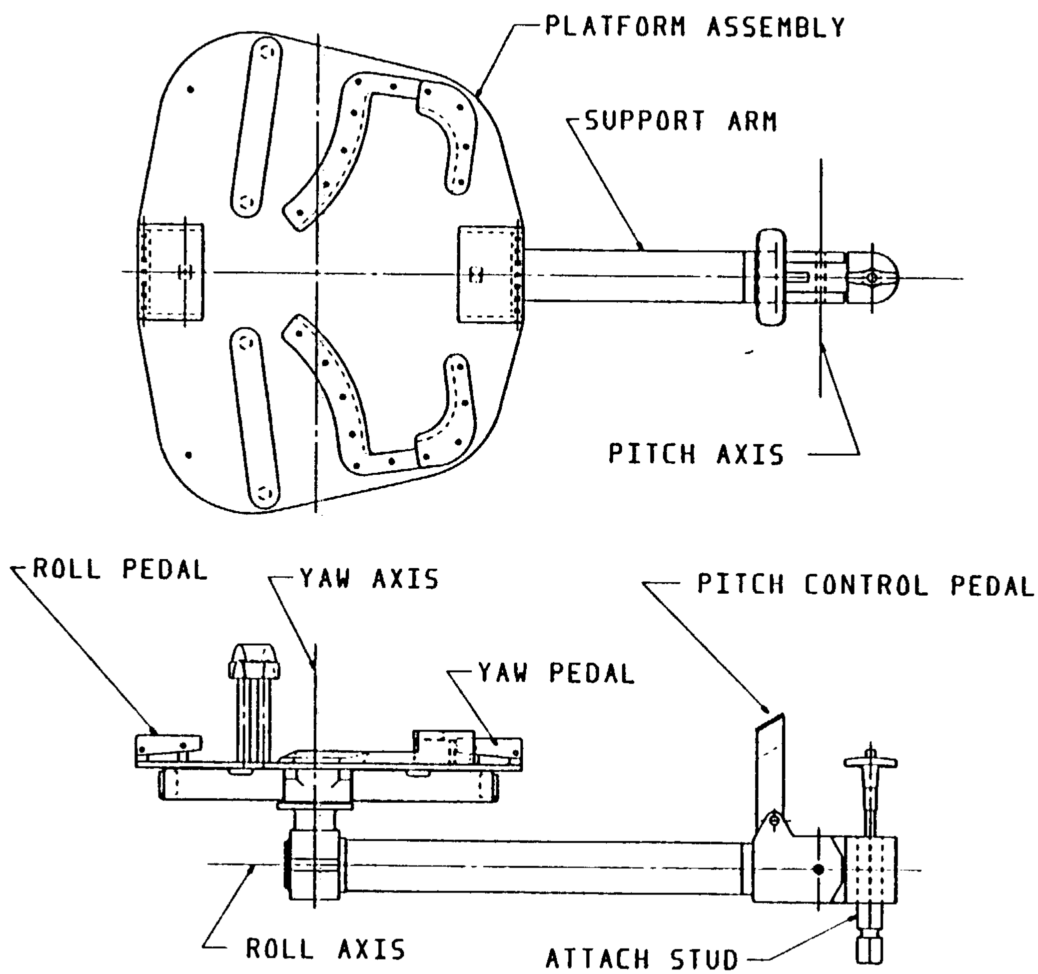
- Ultimate design load is 623N (140 LBF)
- Extension - 5th percentile female to 95th percentile male
- Sized for EMU boot
- Articulation - ± 360° Yaw, ± 360° Roll, ± 30° pitch
- Dimensions - 812 mm (32 in) x 509 mm (20 in) x 330 mm (13 in)
- Mass - 8.16 Kg (18 lbs)
- Power - none

OPERATION: Each satellite service kit is provided with a portable foot restraint (PFR). On missions where periodic servicing is planned, female receptacles for the PFR are included in the spacecraft design at the required servicing sites. For a particular service task, the PFR is brought to the site and locked into the receptacle. Simulated service tests have shown that movement and work capability are severely limited by the fixed PFR. Therefore, articulation in roll, pitch and yaw are included in the redesign which greatly increases the sphere of work activities and lessens or eliminates fatigue stemming from working in awkward positions in the EMU.

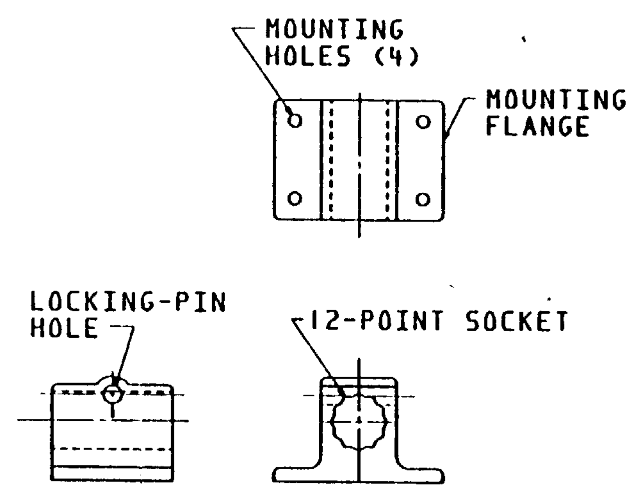
For application in unscheduled servicing operations, the spacecraft/grapple fixture attachment devices shown in the previous chart are directly applicable for PFR emplacement. They employ the same attachment stud receptacle.

APPLICATION: The Portable Foot Restraint is included as part of the Standard mission support modules which are intended to support all service missions.

Portable Foot Restraint



Female Support Receptacle — Portable Foot-Restraint



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PORTABLE GROUNDING STRAP

PURPOSE: Large electrical potential differences are known to build up between and within objects in space. These charges, which can reach values as high as 25,000 volts, are relatively harmless to personnel, because of the low amperages involved, but can cause severe damage to electronic elements and circuitry. Any servicing operation which involves linking a satellite or space debris to the orbiter must include a preliminary discharge of these potentials and the maintenance of a common ground potential. The Portable Grounding Strap has been designed for these purposes.

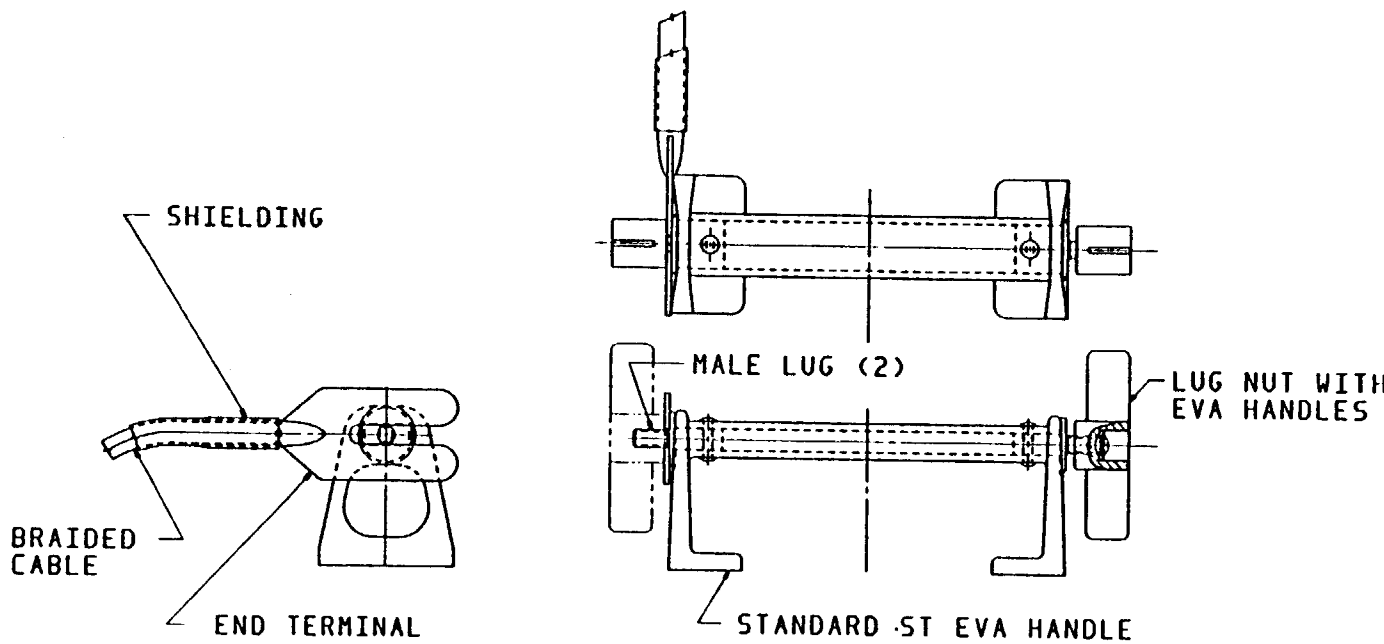
REQUIREMENTS: The principal requirements for this device are:

- Positive, preloaded electrical contacts
- Multi-path electrical conduction
- High flexibility and resistance to fatique failure
- External insulation, compatible with the orbit environment
- High tensile strength
- Physical size (diameter) compatible with space glove manipulation
- Low weight

OPERATION: Each applicable service kit is provided with a coiled, 15 meter length grounding strap. The conductor is a 12mm diameter braided cable made up of copper filaments. The insulating cover is of 1.5 mm thick, high dialectric material which extends over the shanks of the end attachments. The simplest and most reliable attachment method is the post and butterfly nut arrangement shown here, which clamps against a large version of a standard wire terminal. In this application it is shown combined with an EVA equipment handle, but individual spacecraft attachment methods are available. For situations where preplacement on the satellite is not possible, a modified alligator clip with a positive toggle lock (e.g., "Vicegrip®" pliers) is proposed.

APPLICATION: The Portable grounding stap will be used with all service kits with the exception of Deployment and Earth Return. The former mission class has no need for the ground and the latter is provided with mission specific umbilical having its own ground; see next chart.

Grounding Strap Attach on EVA Handle



MATE/DEMATE UMBILICAL

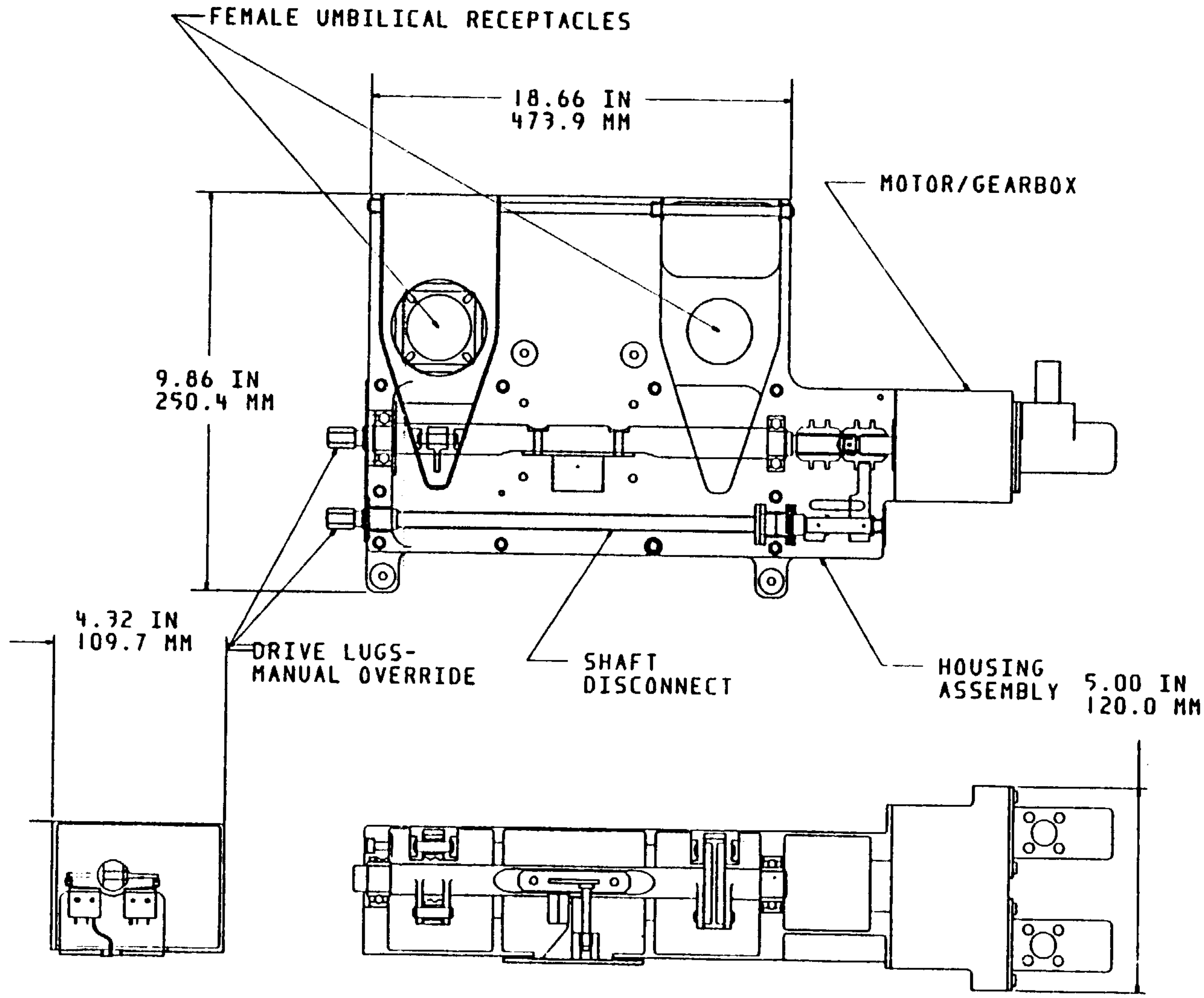
PURPOSE: A definite requirement exists for an electrical umbilical which provides for manual (EVA) connect/disconnect as well as remote disconnect. The umbilical is used prior to satellite deployment, during recovery, and servicing operations as well. In most operations, connector designs conform exactly with requirements for transmission of power, communications, checkout, control data, etc. For planned recovery of non-orbiter launched satellites it is necessary to provide the female umbilical connector unit on the satellite prior to launch.

REQUIREMENTS: The design requirements for the mate/demate umbilical include physical, mechanical/electrical, interface, and human factors considerations.

- Mechanical/Electrical
  - The device shall adequately service and function in all mechanical, thermal, chemical and electromagnetic environments imposed during the total service life as specified in JSC 07700, Vol. XIV and attachments.
  - Grounding same as the portable ground strap.
  - Power and data transmissions are payload specific and are orbiter supplied or accomodated
  - Demate is automatic with manual override; mate is manual (EVA).
- Human Factors requirements are:
  - EMU/EV Glove accessibility (physical, visual, tool Clearance)
  - Maximum manual force at mate = 34 Nm (25 Lb-Ft)
  - Manual override for demate (ratchet wrench/socket) = 2.71 Nm (2Lb-Ft)
  - Display signals for verification of proper mating
  - Jettison capability
- Physical Characteristics:
  - Size is payload specific (ST design shown is 252 mm X 110 mm X 500 mm)
  - Mass (common elements) = 8.8 kg (19.5 lbs)
  - Power is payload specific

OPERATION: Automatic demate is initiated, upon signal, as a part of the satellite deployment sequence of events, and is accomplished thorugh the medium of dual camshafts operated by either of two redundant electric drive motors. The cams, which drive the male connectors (two, in the accompanying figure) out of the the female sockets, can be operated manually, using a 7/16 inch socket and ratchet wrench on the hexagonal extensions of the cam shafts. After separation pre-loaded cables and takeup reels draw the male connectors into stowage cradles at the Orbiter bulkhead.

Mate/Demate Umbilical



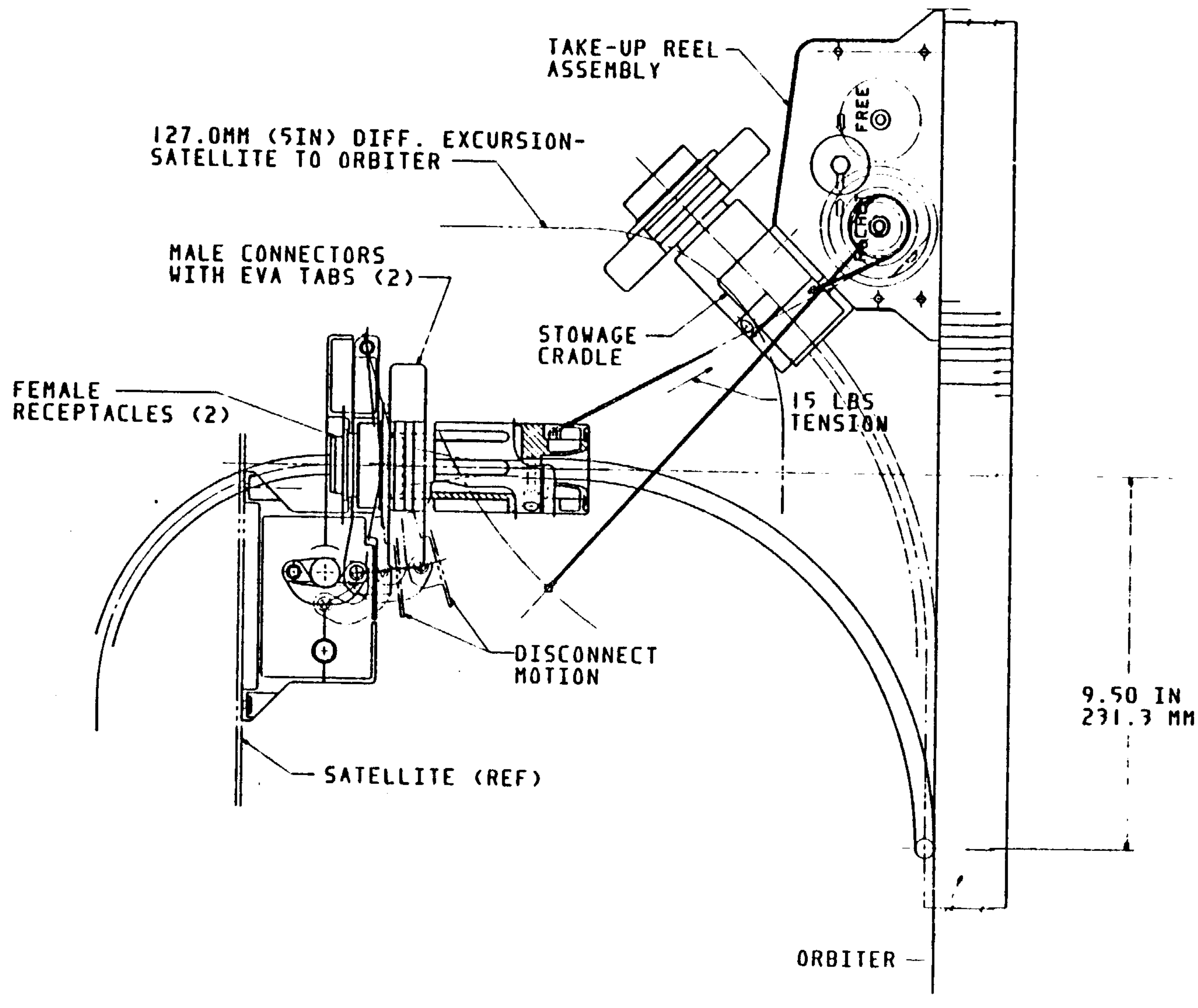
MATE/DEMATE UMBILICAL (CONT)

OPERATION: (continued)

Mating procedures are always manual, whether performed prior to Orbiter launch or as a part of EVA activities after satellite recovery for servicing or earth return. After insertion of the male connectors in the female receptacles, final lock-in is accomplished through a quarter turn of the large butterfly handles on the connectors (locks are overridden during the auto-demate).

APPLICATION: The Umbilical, Mate/Demate is a part of service kits for Sortie, Changeout/Resupply Reconfigure, and Earth Return missions.

Mate/Demate Umbilical



SHARP CORNER/EDGE PADDING

PURPOSE: Provisions are necessary for elimination of hazards to the crew during EVA posed by sharp corners, edges, and protruberances encountered on satellites or debris not specifically designed for EVA. The most practical approaches for removing these hazards involves the padding of sharp edges and the coating of sharp protruberances. The first approach entails the provision of padding which has a smooth, tough outer surface backed by a layer of soft spongy material, and an inner surface coated with a bonding agent suitable for use in-vacuum. The sharp protruberance coating substance must be easily applied with a suitable applicator and must present a smooth, non-snagging, and non-sticky surface after application.

REQUIREMENTS: The principal requirements which must be satisfied in edge and corner padding are:

- A variety of preformed shapes which anticipate the most common flange and corner configurations on satellies
- Non-gas-off, non contaminating materials throughout.
- Quick, vacuum setting bonding agent on pads which can be activated at the EVA work site.
- Soft, spongy inner layer capable of attenuation of inadvertent impacts and scrapes.
- Pad conformance to EVA glove manipulation requirements.

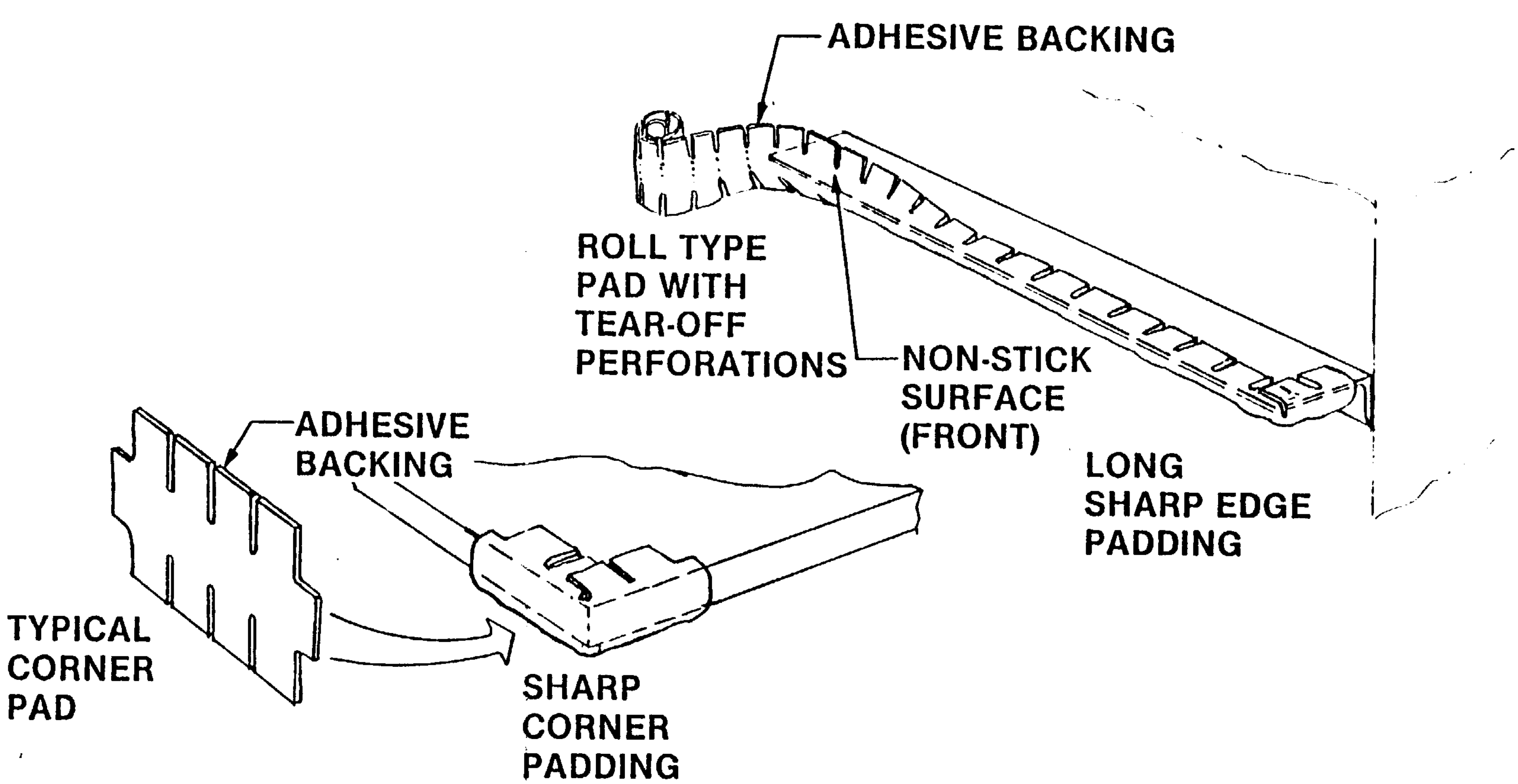
Protruberance coating material shall have:

- Proper flow consistency for zero G and vacuum handling.
- Quick setting characteristics.
- Adhesion to all hazardous elements
- No gas-off or contamination

OPERATION: An assortment of pads an a protruberance coating applicator is transported to the EVA work site in a carrying/stowage case. Upon selection of a suitable pad for covering a particular hazard, the crew member activates the anarobic bonding agent by stripping the cover from the inside surface of the pad (tabs suitable for EMU glove manipulation are provided for this purpose). The pad is then folded about the flange or corner and held in place until the glue begins to set. When all flanges/corners in the work area have been covered, sharp protruberances such as bolt heads, pins, safety wire, etc. are coated with coating applicator. The next chart describes the applicator and coating substance.

APPLICATION: Sharp Edge/Corner Padding is a part of the Sharp Edge Padding Kit which is part of the service kit for each mission type.

Sharp Corner Padding



SHARP PROTRUBERANCE COATING APPLICATOR

PURPOSE: Sharp projections or protruberances such as bolt heads and threaded ends, cotter keys, safety-wire ends, jagged holes, etc., must be anticipated as a hazard on servicable satellites and space debris. Since the use of sharp edge and corner padding is impractical for covering a large number of relatively small hazards, the most attractive scheme is to cover them with a coating of substance which renders them smooth and harmless, as described in the previous chart. For the purpose of applying this substance, a calking gun suitable for use in space and operable by a suited astronaut is required. Conveniently, a device developed and tested for use in orbiter tile repair is equally suitable for use as a Sharp Protruberance Coating Applicator with a small change in flow nozzle shape and material formulation.

REQUIREMENTS:

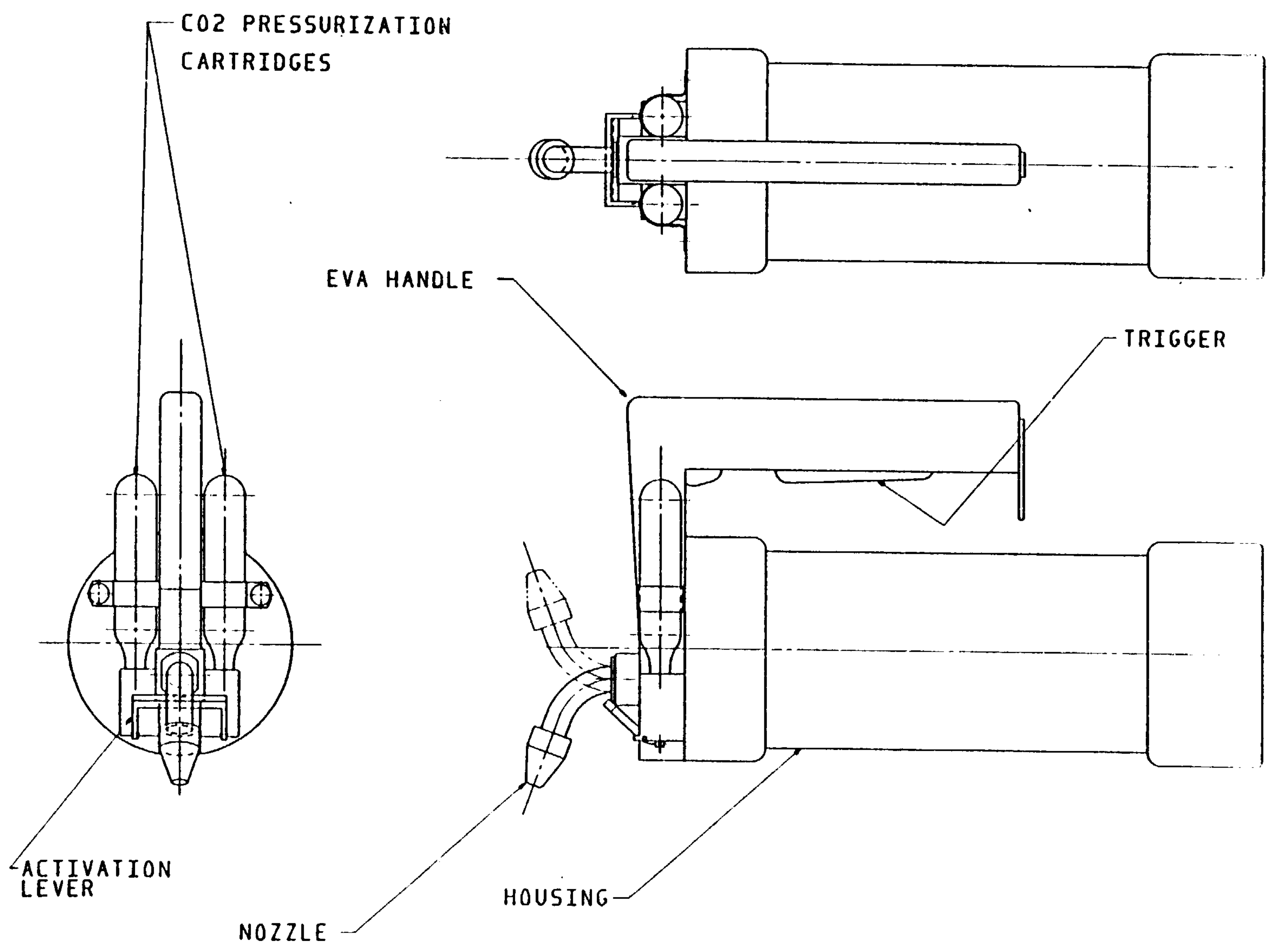
- Small size and mass for ease of handling and stowage in pad carrying case
- Automatic, hand triggered operation
- Quick, Reliable shut-off
- Handle designed for suited use
- Coating material conforming to requirements stated in Sharp Corner/Edge Padding text.

OPERATION: The main housing of the applicator is made up of three concentric cylinders. The innermost cylinder contains the static mixing units for mixing the coating components prior to expulsion through the nozzle. The space between this and the next cylinder contains the catalyst and the outermost space contains the resin. The resin is an RTV polymer. The motive force for mixing and expulsion of the coating materials is provided by two CO_2 cartridges. Operation is initiated by a downward stroke of the CO_2 activation lever. A trigger mechanism in the carrying handle meters pressure into the two outer chambers and behind the double drive pistons. The latter are linked by a cutting blade which splits the intermediate nylon cylinder permitting uniform movement of the pistons and thus the monomer components through the mixing chamber and nozzle. Included in the trigger linkage is a contingency cutoff lever at the forward end of the carrying hand. This insures that over flow does not occur.

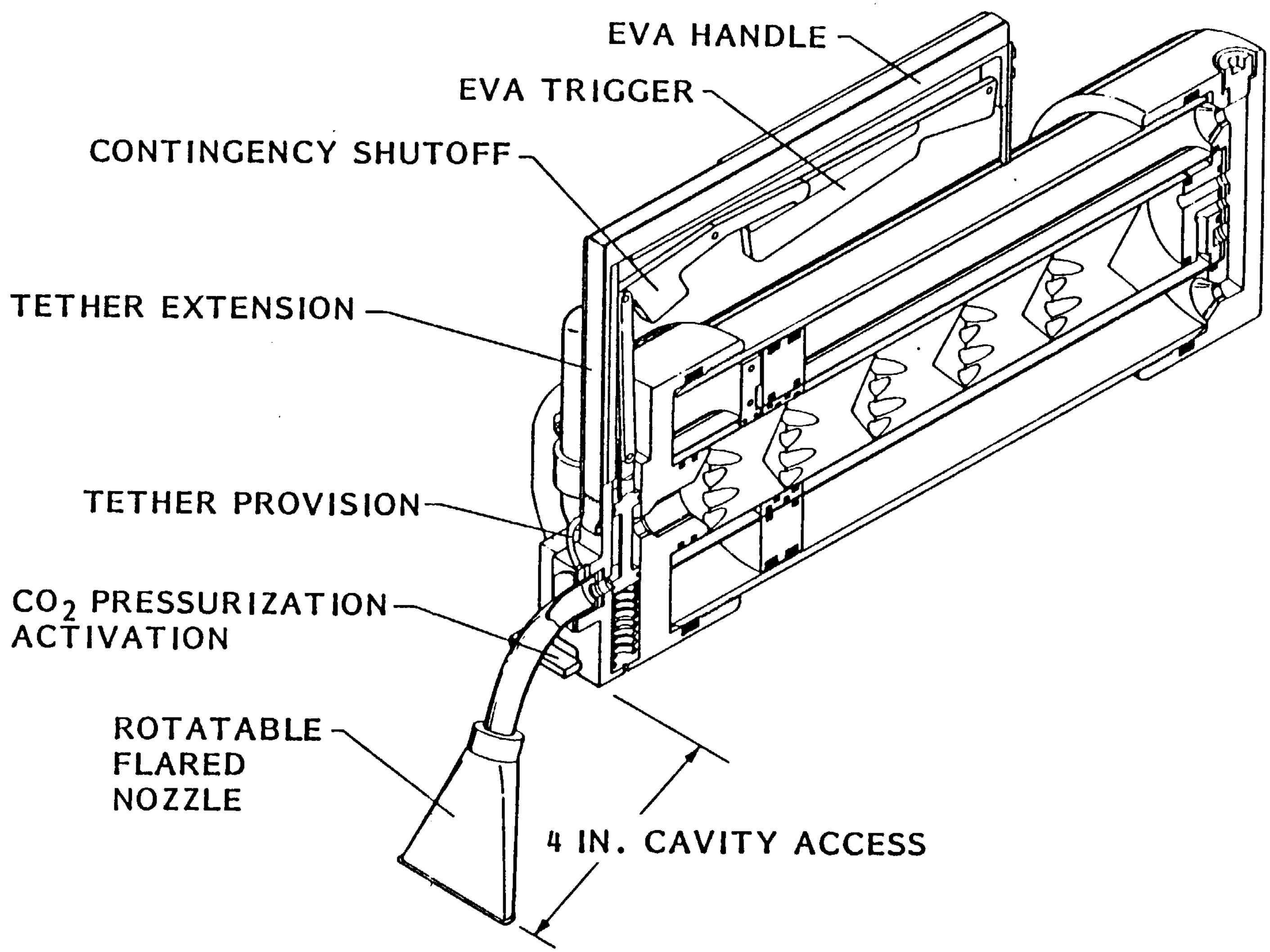
Since the setting time for the particular mixture used in the repair kit was considerable in excess of that required in this application, the mixture ratio and thus the relative volumes of the resin and catalyst chambers require redesign. Final mixture ratios for this application remain to be determined on the basis of time line analysis and simulation.

APPLICATION: As a part of the Sharp Edge Padding Kit, the Applicator is included on all service missions.

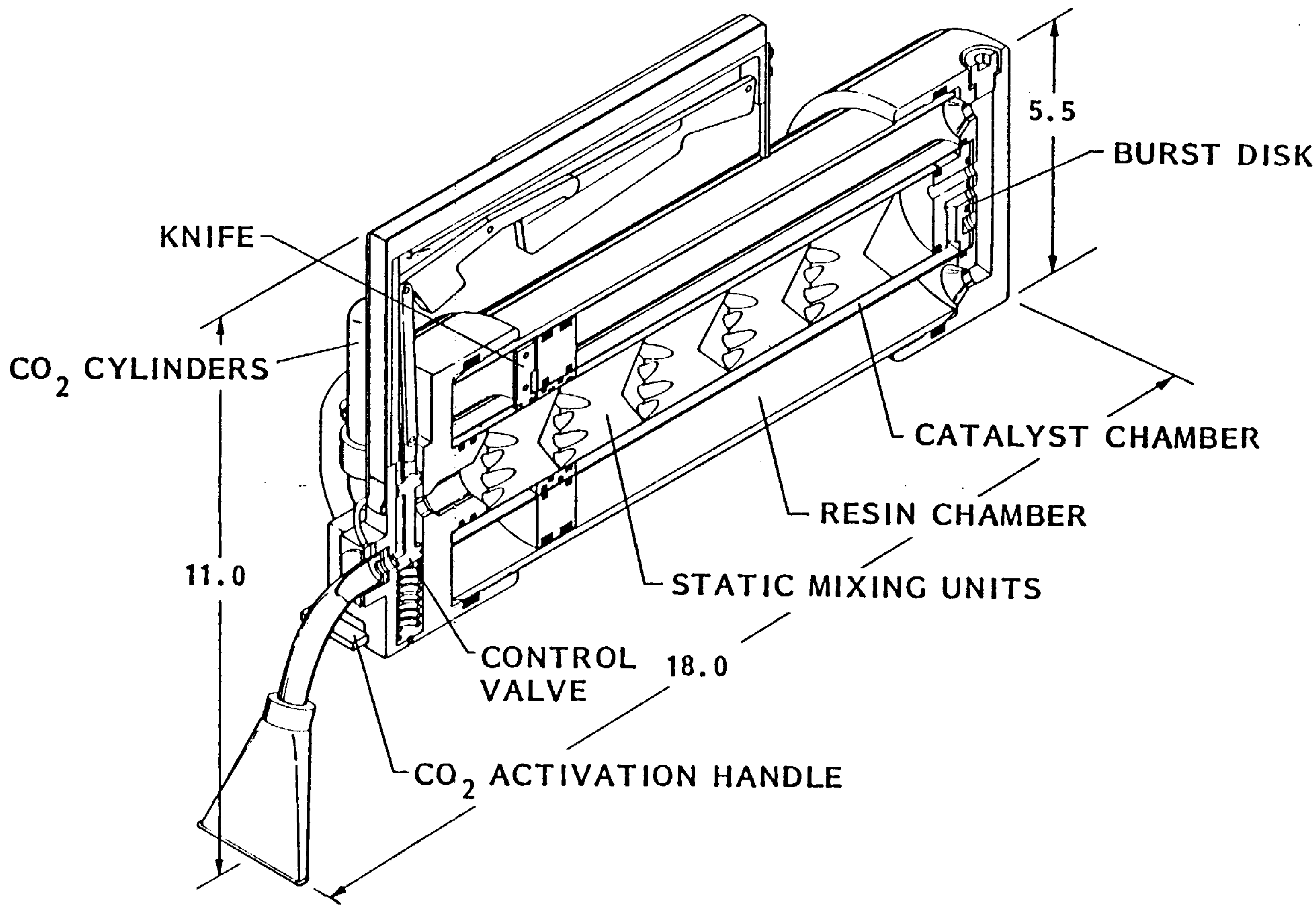
Protruberance Coating Applicator



Applicator/Mixer



Applicator/Mixer



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SHARP CORNER/EDGE PAD KIT

PURPOSE: Previous figures and text have dealt with the methods and devices and materials necessary to the elimination of the hazards posed by sharp flanges, edges, corners and protruberances. In the interests of simplifying the task of transporting the padding and coating elements to the work site as well as providing a protective environment, a carrying case suitable for EVA use has been designed. The kit is comprised of the carrying case, an assortment of pad shapes and sizes, and a sharp protruberance coating applicator.

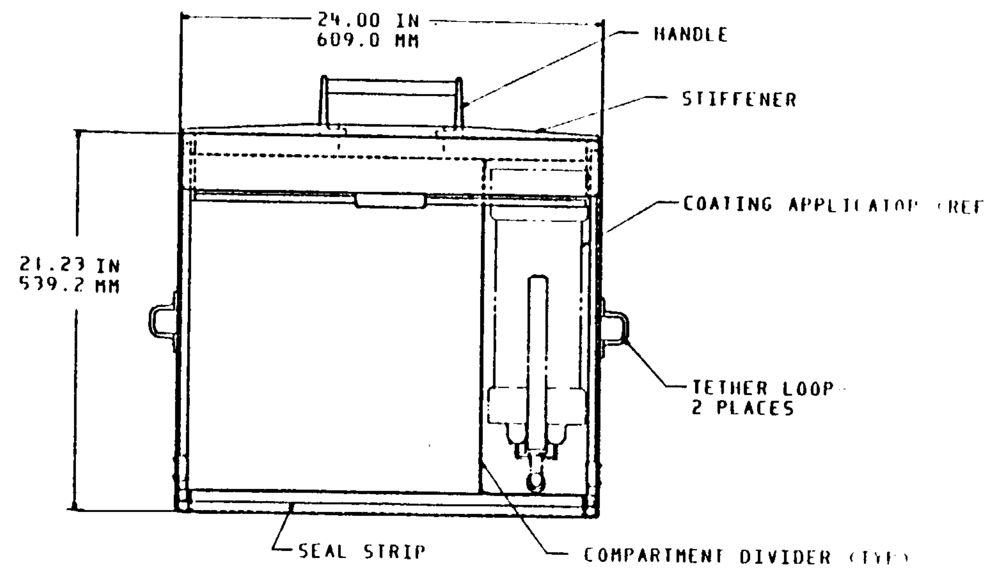
REQUIREMENTS: The kit requirements are:

- Size & weight suitable for ease of EVA transport & handling.
- Carrying handle & safety tether loops.
- Smooth surface, rounded corners.
- Easily manipulated cover with "self parking" characteristics.
- Adequate sealing/protection during transport.
- Method for handling pads and applicator in place in Zero-g prior to use.

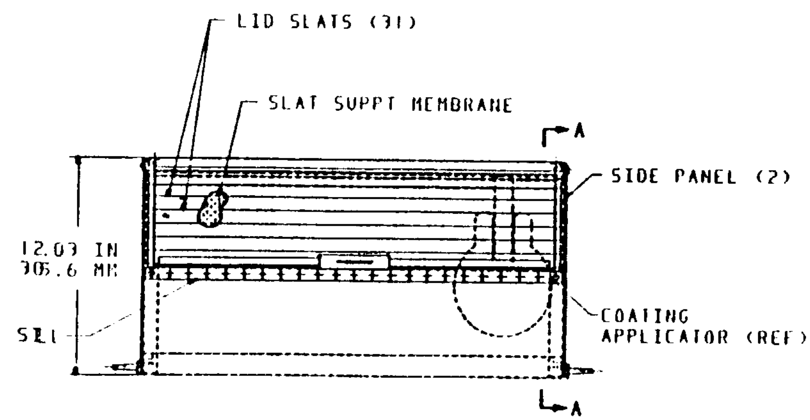
OPERATION: The kit is transported to the work site by carrying handle or belt tether. Access to the contents is achieved by sliding back the "Roll top" cover using the lid handle. The latter is a cam-action device which allows the lid to slide when pushed or pulled in a direction parallel to the lid surface, but which locks the lid at whatever position the handle is released. Pads are held in the kit by means of a Velcro R attachment between their bottom edges and the kit liner. The applicator is attached to the inside floor of the kit by means of two spring clips.

APPLICATION: The Sharp Edge Padding Kit is included in the service kit for all service missions.

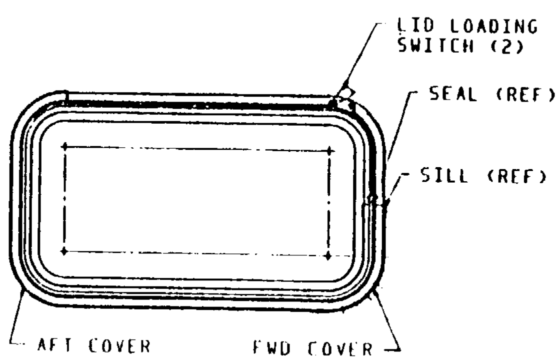
Sharp Corner/Edge Pad Kit



TOP VIEW - LID OPEN



FRONT VIEW - LID CLOSED



SECTION A-A

DEPLOYMENT AND MAINTENANCE PLATFORM
(SATELLITE EXTRACT/INSERT PIVOT/ROTATE TABLE)

PURPOSE: The "Satellite Extract/Insert Pivot/Rotate Table" was identified as a needed service tool in Part I of the SSSA Study. It is an outgrowth of the Deployment and Maintenance Platform being developed for the Space Telescope. This platform is designed to perform the functions of aiding the deployment of the spacecraft or stowing it for earth return. In this respect it performs the functions sometimes referred to as the "Payload Insertion and Deployment Aid". As added functions, it provides a berthing platform which holds a recovered satellite. Its pivoting and rotation capability support maintenance (service) operations from the orbiter bay. These latter functions are sometimes referred to as "Holding and Positioning Aid ". For clarity and functional distinction, the table is referred to as the "Deployment and Maintenance Platform " (DMP).

REQUIREMENTS: In meeting its design goals, the DMP shall:

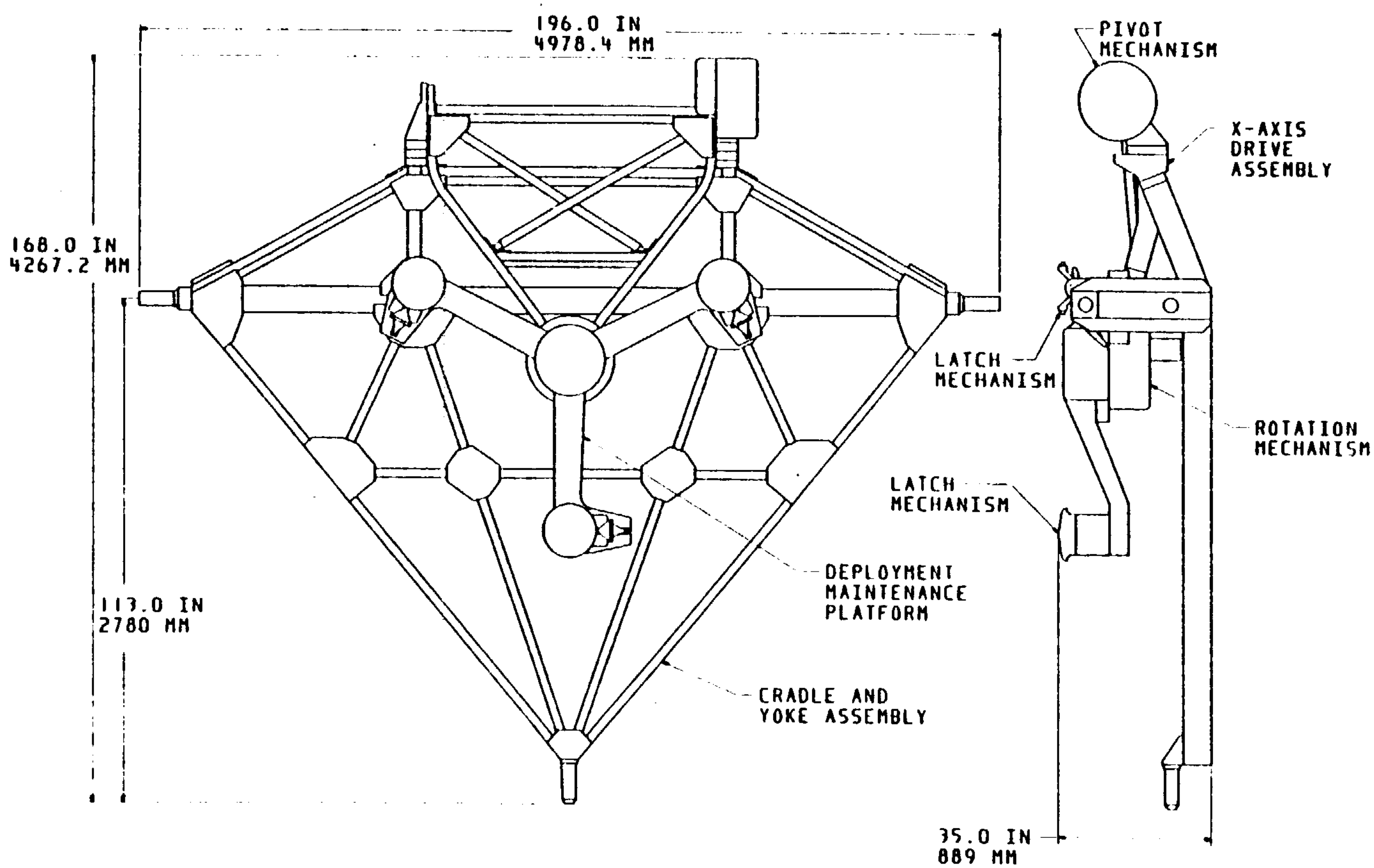
- Survive all orbiter service environments included in the periods of pre-launch, launch, and orbit injection, orbit operations, entry and landing.
- Berth and manipulate satellites accurately and safely.
- Tilt the payload out of the cargo bay to a checkout and separation position.
- Rotate for appendage deployment ORU maintenance and refurbishment (i.e., bring the work to the EVA crew persons).
- Stow and latch satellite for earth return.
- Maximum Mass 567 Kg (1250 lbs)
- Operate on 115 VAC, 400 Mz ± 7Hz power supplied by orbiter

OPERATION: The DMP is designed to act as the aft launch support on relatively light weight satellites, which it supports by means of the latch mechanisms on its deployment mainteannce platform. For large payloads, such as the Space Telescope, the platform is swung aft of but aligned with the satellite latch interfaces. Upon achieving orbit and opening of the cargo bay doors, the deployment maintenance platform is attached to the large satellite, cargo bay trunnion attachments are released, and the satellite is tilted into a vertical (Z-axis) position by means of the pivot mechanism. The Satellite is then turned by the rotation mechanism to a position which insures that deploying appendages will clear all parts of the Orbiter. Final appendage deployment and spacecraft checkout

Deployment and Maintenance Platform

(SATELLITE EXTRACT/INSERT PIVOT/ROTATE TABLE)

STOWED



OPERATION: (Continued)

takes place. Finally, the RMS is engaged, latch mechanisms released and the satellite is removed to the deployment position and attitude. Retrieval and stowage of a satellite for earth-return is the reverse of the foregoing procedures. In missions where refurbishment, equipment change-out, and maintenance is sole objective, the satellite is retrieved and berthed to the DMP and latches are engaged. After retraction of appendages (auxiliary power from the orbiter may be required for this operation), the planned worksites on the satellite are rotated to the crew member. The required replacement units and supplies are loaded. After refurbishment, appendage deployment, and checkout, latches are released and the RMS places the satellite in the separation position.

APPLICATION: The DMP is used for Repair, CR&R, and Earth return missions.

Deployment Maintenance Platform

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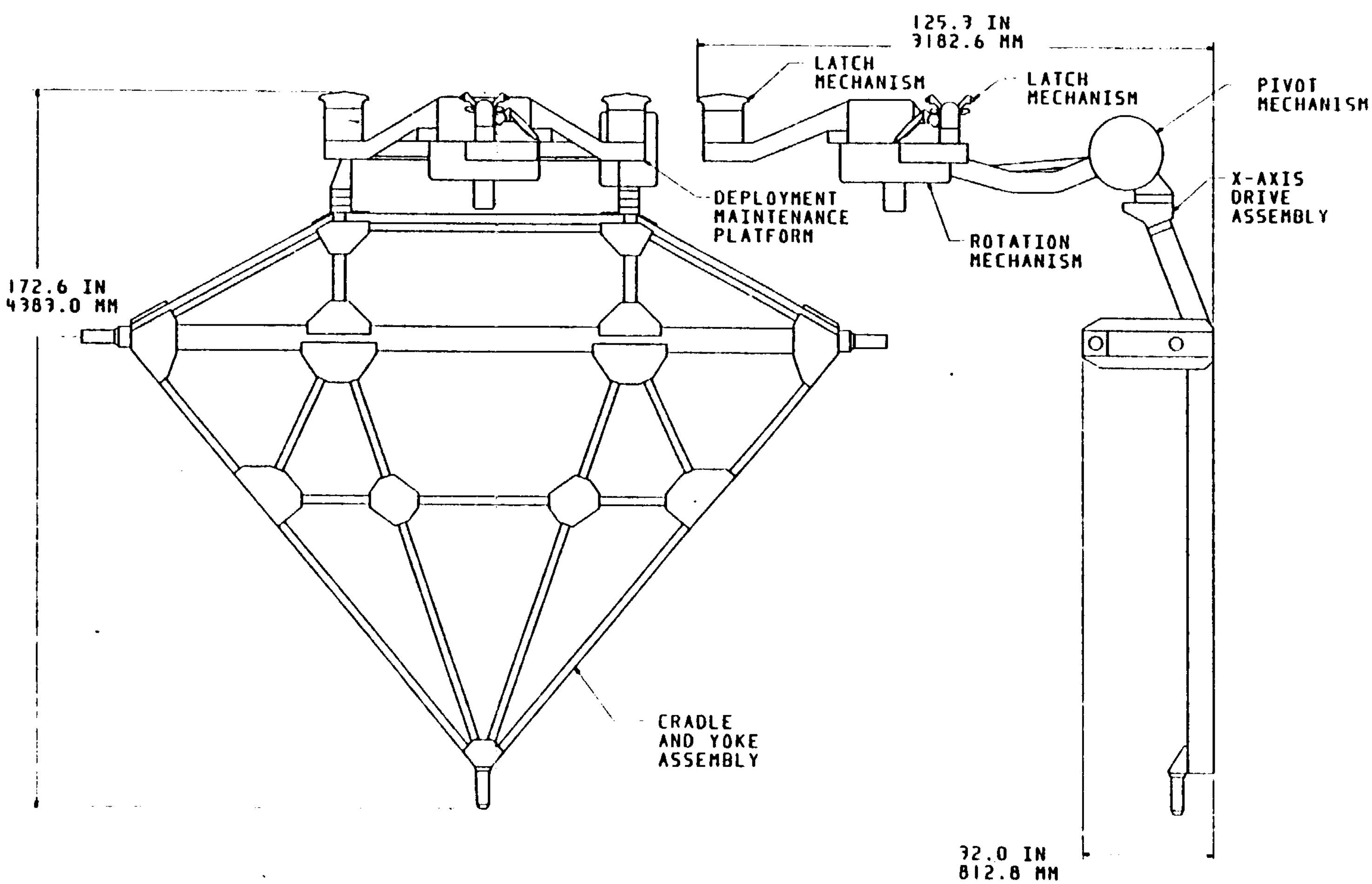
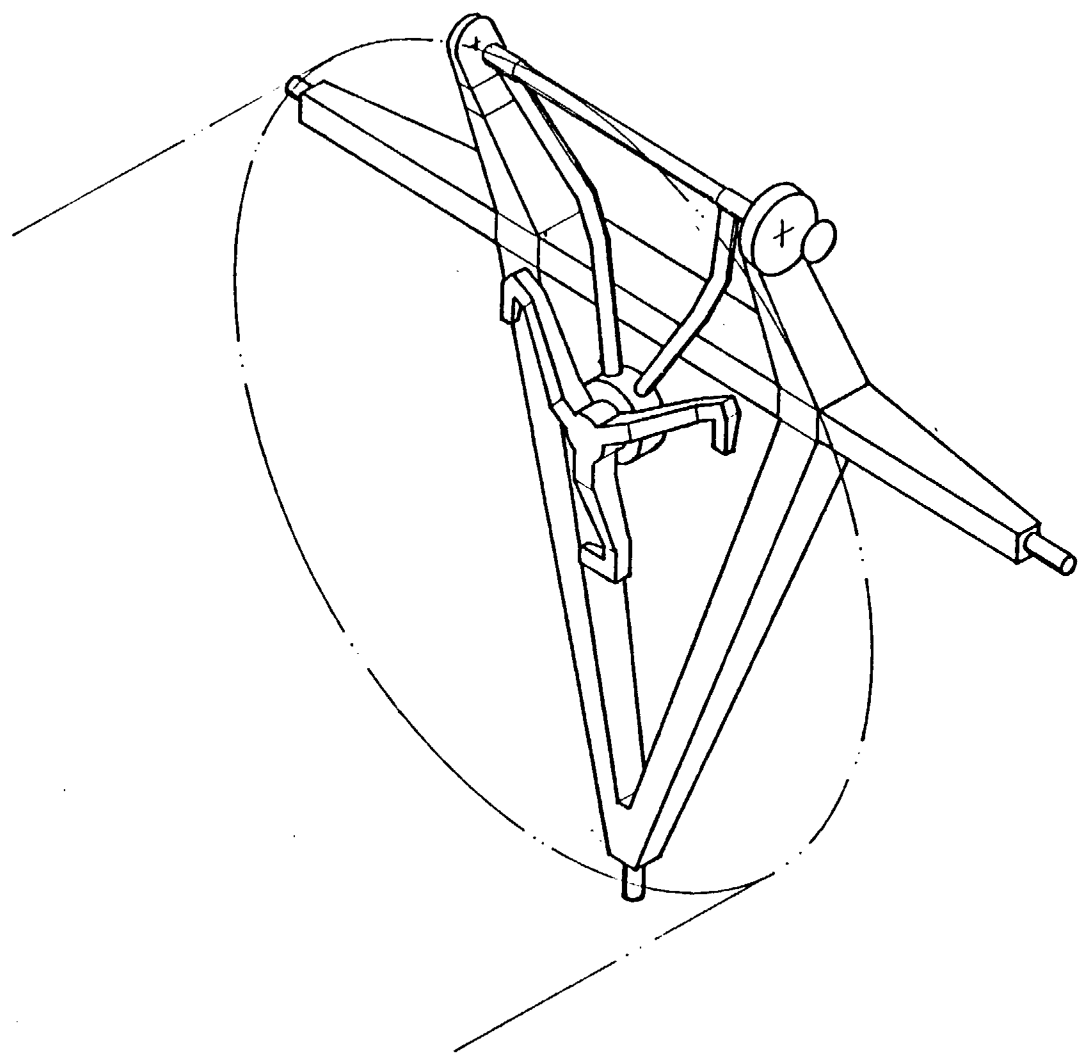
EXTENDED



PERSPECTIVE



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CARGO BAY RACK/TIE-DOWN PLATFORM

PURPOSE: This structural assembly serves several functions. In the first of these, it is used as an intermediate stowage or handling area when a number of tools must be brought from the stowage container to the satellite work site. Secondly, it provides an open, flat surface used as a work bench for planned and unscheduled service operations. Finally, it serves as a cargo tie-down platform for use in recovery/earth return operations of satellites and space debris which have no provisions for normal cargo bay stowage.

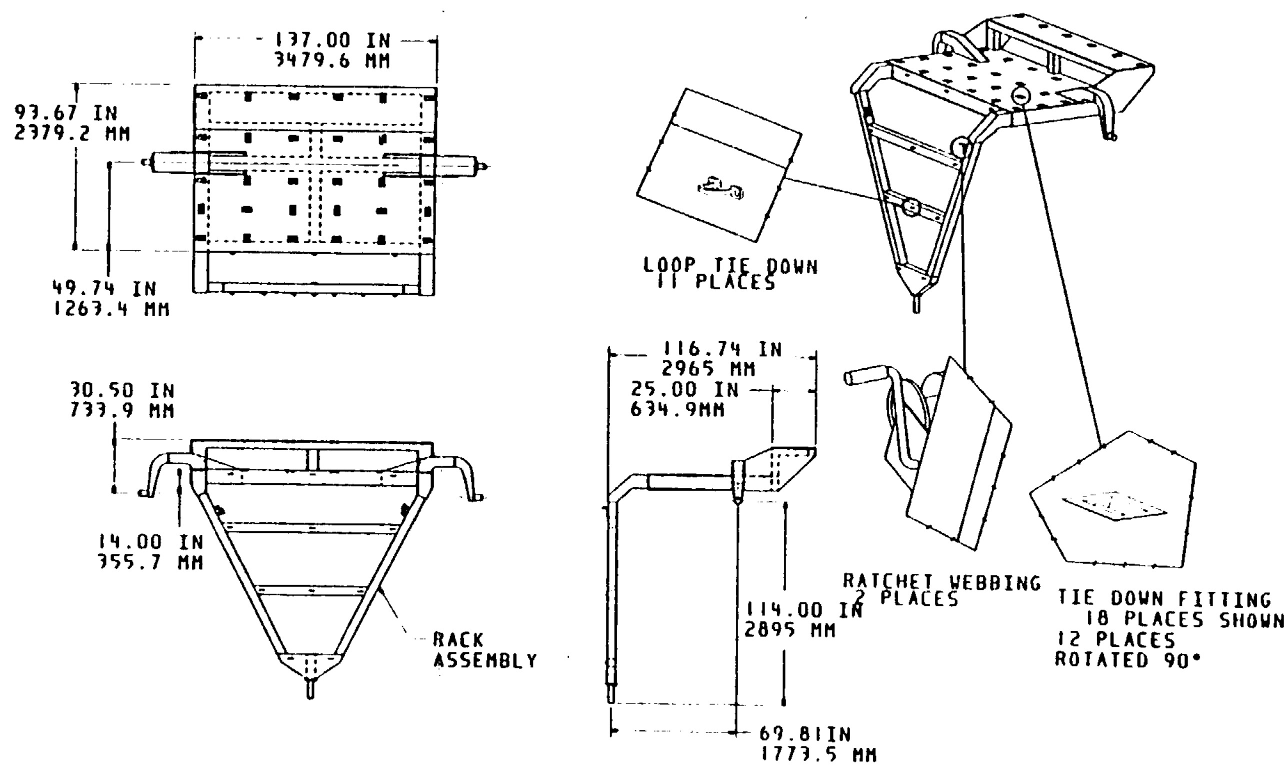
REQUIREMENTS: The Rack/Tiedown Platform shall:

- Survive all orbit, entry, and landing environements when supporting a payload of not more than 450 Kg (1000) lbs.
- Provide a number of attachments at locations on the structure convenient for intermediate tethering of SSS equipment and tools during transport to the EVA worksite.
- Provide work holding devices (clamps, vise, "Third hand" holding jaw) for work bench application.
- For cargo tie-down provide recessed tiedown fittings in the deck to be used with standard aircraft-type tiedown straps and cinches. Also provide cargo winch for tightening rope/cable tiedowns.
- Be placed in unused cargo space (e.g., over OMS Kit).

OPERATION: This is a passive structure which does not "operate" in the normal sense of the word. Its multiple functions are stated above, and a typical servicing task must be postulated to describe these functions. Suppose that an existing, spent satellite, not designed for Shuttle, is being recovered for on-orbit repair/refurbishment or earth return. After rendezvous, attachment of a portable grapple fixture and a grounding strap, any appendages are removed or stowed. It is then grappled by the RMS and brought to the deck of the rack and oriented so that it fits within the cargo bay clear volume. Then, using the tie-down provisions, it is strapped to the rack deck and examined. If refurbishment and replenishment are possible, the tools for those tasks are brought aft from the stowage container and tethered to the rack and the work proceeds. If refurbishment is not possible, but earth return is desired, any appendages interfering with cargo bay doors or incapable of withstanding the reentry and landing loads are severed. The satellite is then rearranged on the rack to sustain the reentry loads and strapped down for earth return. It is obvious that satellites which do not fit within the stowage envelope or which exceed the design weight limit of the rack will not be candidates for recovery in this manner.

APPLICATION: The Cargo Bay Rack/Tiedown Platform is applicable to the Sortie and CR&R missions in addition to the Earth Return.

Cargo Bay Rack/Tiedown Platform



3. Program Plans

3.1 SATELLITE SERVICES PROGRAM PLAN

3.2 SATELLITE SERVICES DEVELOPMENT PLAN

3.3 SATELLITE SERVICES OPERATIONS PLAN

S^3 PLANNING PERSPECTIVE

An evolutionary approach is proposed for the development of the Satellite Services System, in order to keep early year funding relatively low and to take advantage of the existing and soon to be available service equipment.

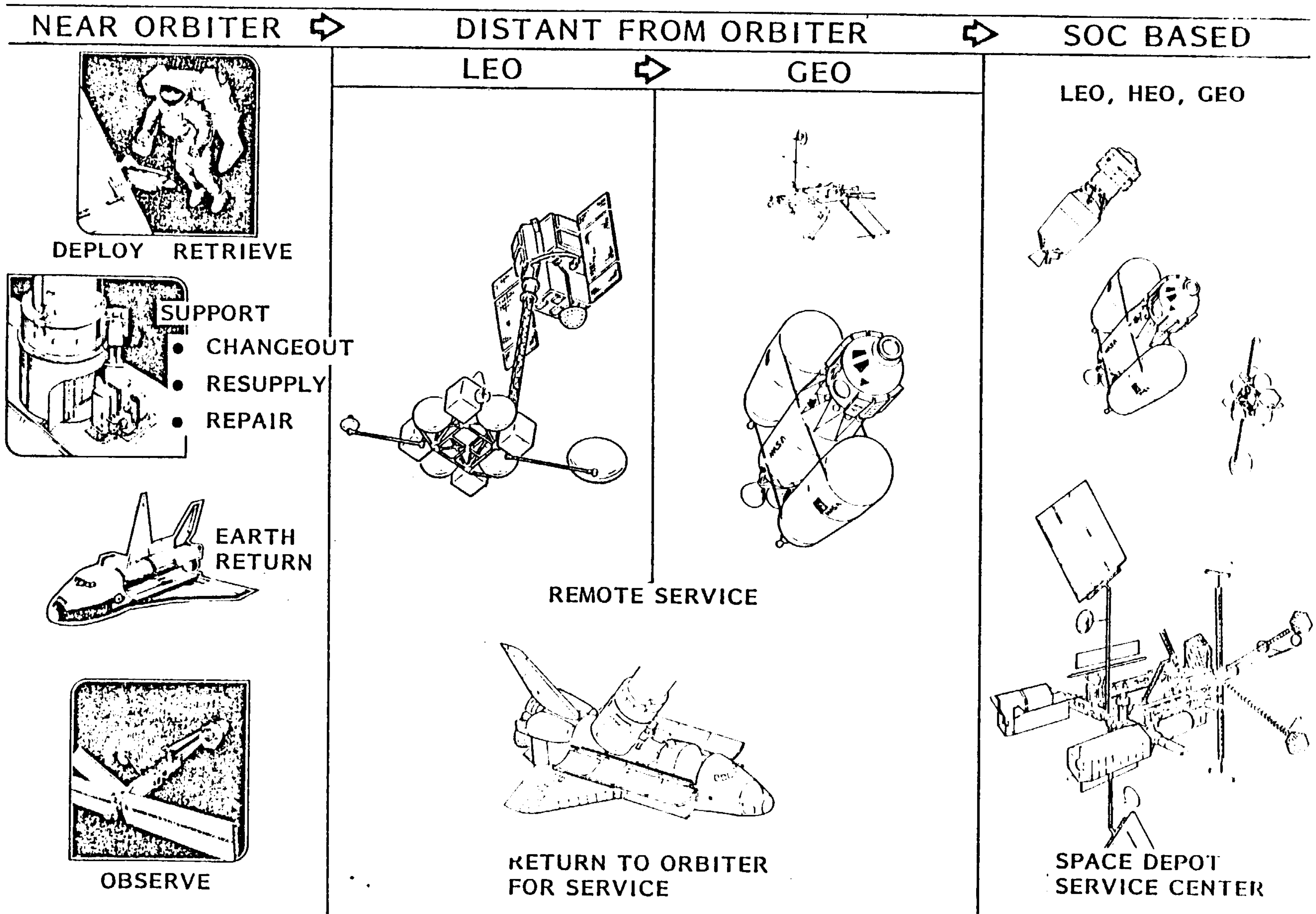
Three major evolutionary steps are envisioned:

INITIAL: Near-Orbiter servicing, involving satellites and services in LEO, directly accessible by the STS

EXPANDED: Distant from Orbiter servicing, first in LEO not directly accessible by the STS and subsequently in GEO.

SPACE BASED: With the availability of the Space Operations Center in 1989=1990, space based servicing will become possible for co-orbiting satellites, and satellites in LEO, HEO and GEO.

S3 Planning Perspective



NASA

3.1 Satellite Services Program Plan

INTRODUCTION
SYSTEM REQUIREMENTS
SYSTEM DESCRIPTION
WORK BREAKDOWN STRUCTURE AND SCHEDULE
SYSTEM INTEGRATION APPROACH
MAJOR SUPPORT SYSTEMS AND INTERFACES
FACILITIES
IMPLEMENTATION PLAN

Lockheed

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NASA

Introduction

Lockheed

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S^3 MISSION FUNCTIONS

To provide the maximum cost benefits and to simplify the functioning of a satellite servicing system, an integrated effort is indicated in which common equipment and facilities are utilized. This program plan is based upon this premise.

The S^3 coordinates the user needs for servicing equipment and provides designs and operating methods that can apply to many space missions.

Preplanning for forthcoming and future mission support ensures that necessary S^3 equipment is available when needed. A storage depot keeps on ready status the spare components and S^3 modules and kits to be manifested for STS-supported missions.

A ground repair and refurbishment depot cycles failed or worn S^3 equipment; the equipment is renewed for further space use. This approach, as opposed to buying new equipment, results in significant cost saving.

Because of the rapidly expanding space operations with the Space Shuttle, special attention is paid to having proper types and quantity of spares. Further, the widened use of expendables for resupply of long-duration space missions merits strong consideration of bulk buying and storage in common-use facilities. Therefore, an integrated logistics supply effort is planned for the S^3 operations.

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S3 Mission Functions

- UNIVERSAL SPACE SERVICING
  - DEPLOYMENT
  - OBSERVATION
  - RETRIEVAL
  - SUPPORT
  - EARTH RETURN
- INTEGRATED FLIGHT OPERATIONS PLANNING
- SPACE STORAGE DEPOT (SOC)
- GROUND REFURBISHING/STORAGE DEPOT
- INTEGRATED LOGISTICS SUPPORT
  - CONSOLIDATED SPARES PROVISIONING
  - BULK PROCUREMENT/STORAGE OF EXPENDABLES

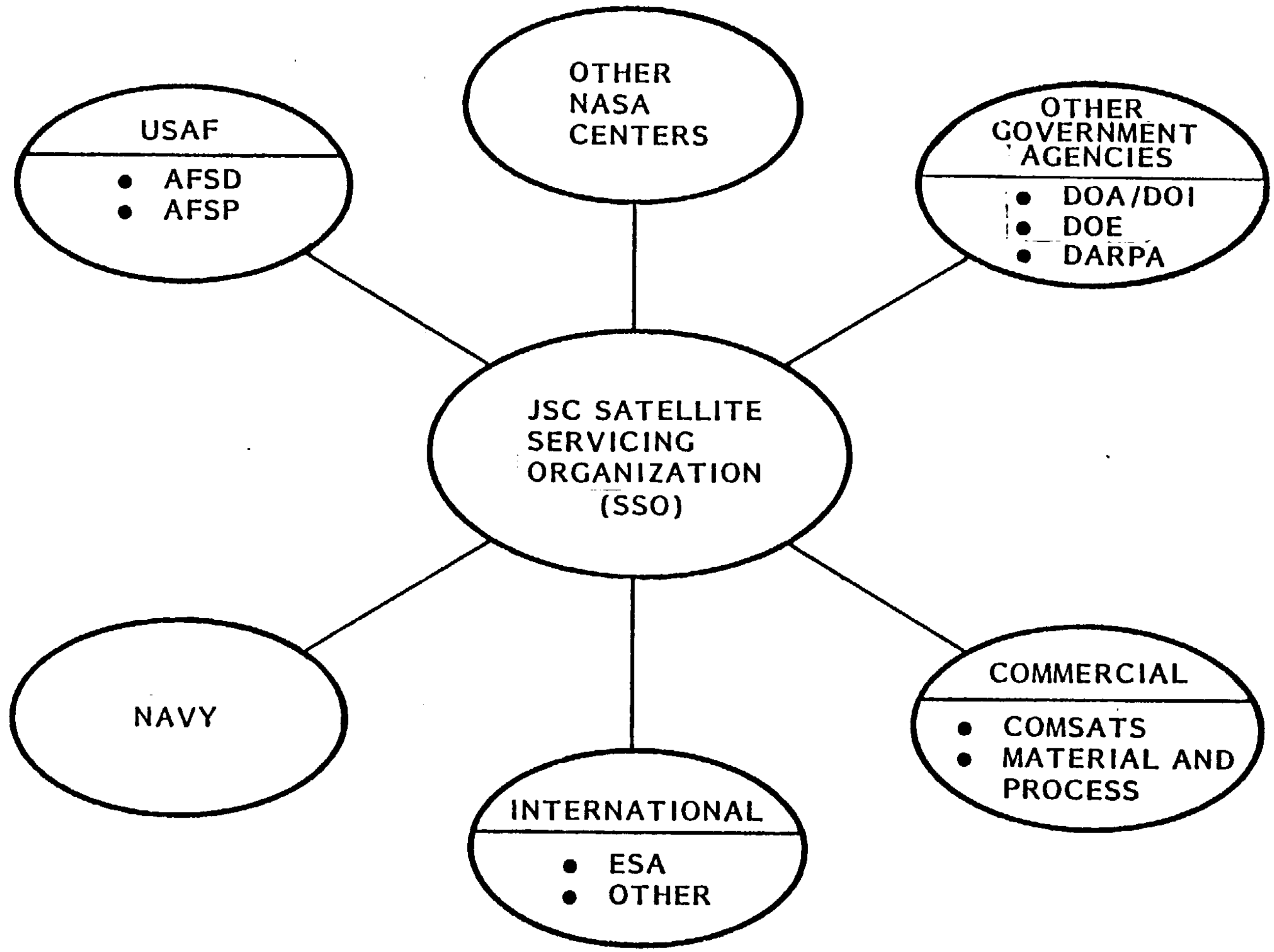
S^3 MISSION OBJECTIVE

The principal objective of the S^3 implementation is a standardized space servicing system utilized by all agencies with satellite and planetary programs. Lacking this approach, the space operations of the 1980's can become a complicated series of project-unique operations.

A central organization is defined to integrate the needs and operations of the various large user agencies and individual users. S^3 can support a wide variety of users and space vehicles if the proper planning is done. The central-management approach is presented later in a separate chart.

S3 Mission Objective

PROVIDE A STANDARD SATELLITE SERVICING SYSTEM TO SUPPORT A WIDE VARIETY OF SPACE MISSIONS



System Requirements

SYSTEM REQUIREMENTS

The principal overall system requirements are enumerated here. The near term application of satellite services is limited to near-orbiter operations. This implies either accessibility of the serviced satellite by the orbiter or the maneuvering of the satellite to the STS accessible orbit by its own capability or a separate autonomous transfer vehicle capability.

Key to the utility of the S^3 is its application to a wide spectrum of the national space resources. This approach permits the application of common equipment and operations to the various users. The implication of this requirement is that the various user agencies cooperate in making use of the common equipment and design their space vehicles to be compatible therewith.

All servicing is intially planned to be orbiter based. Future trends to Large Space Platforms and Space Operations Centers indicate that early equipment and operations development be oriented to eventual application on such space stations.

System Requirements

- SUPPORT ALL LEO MISSIONS
  - DIRECT ACCESS BY ORBITER
  - ACCESS BY USE OF TELEOPERATOR MANEUVERING SYSTEM (TMS)
  - RETURN TO ORBITER BY SELF-CONTAINED PROPULSION
- UTILIZE MULTIMISSION APPROACH (FOR LOW COST)
  - COMBINE DEPLOYMENT AND SERVICE FLIGHTS TO A COMMON ORBIT
- USE COMMON S^3 EQUIPMENT WHERE POSSIBLE
  - ADD SPECIAL EQUIPMENT FOR MISSION-UNIQUE REQUIREMENTS
  - ALTER SOFTWARE TO ACCOMMODATE MISSION-UNIQUE REQUIREMENTS
- ALL SERVICING TO BE SUPPORTED BY STS
  - ORBITER – INCLUDING OMS KITS
  - FLIGHTS FROM ETR AND WTR
- INITIAL S^3 EQUIPMENT TO INCORPORATE GROWTH POTENTIAL
  - LATER USE WITH LARGER SPACE VEHICLES AND PLATFORMS
  - TRANSITION FROM PORTABLE SERVICE PLATFORM (ORBITER) TO FIXED ORBITING PLATFORM (SPACE OPERATIONS CENTER OR EQUIVALENT)

TYPICAL EARLY SATELLITES

The Program Plan is based upon in-depth analysis of an inventory of satellites space platforms, and other space vehicles. Their servicing needs were reviewed and servicing equipment concepts were developed.

Examples of some early satellites which are candidates for near-orbiter service are shown.

The Galileo satellite attached to an upper state, IUS, is carried to LEO by the Shuttle. This is a planetary vehicle; its servicing is therefore limited to deployment in LEO and checkout.

The Space Telescope and the Solar Max Mission have been designed for retrieval and servicing by replacement of Orbit Replaceable Units (ORU's). Failed ORU's will be returned to Earth and repaired or refurbished for reuse.

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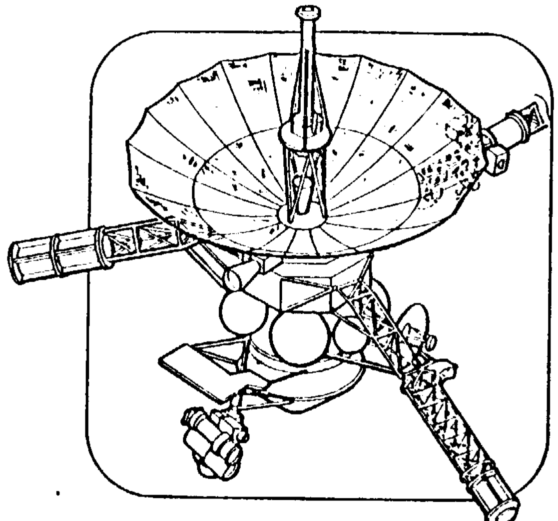
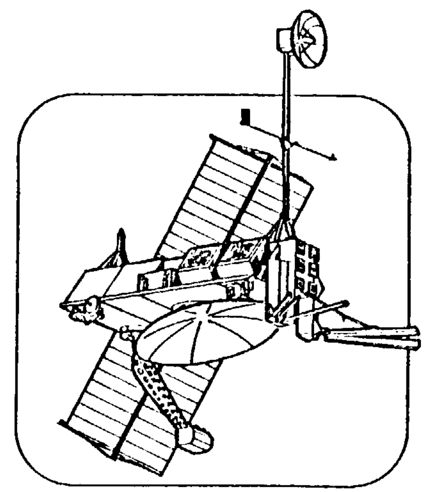
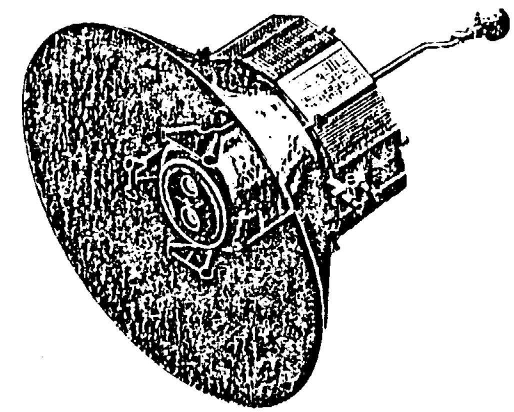
Typical Early Satellites



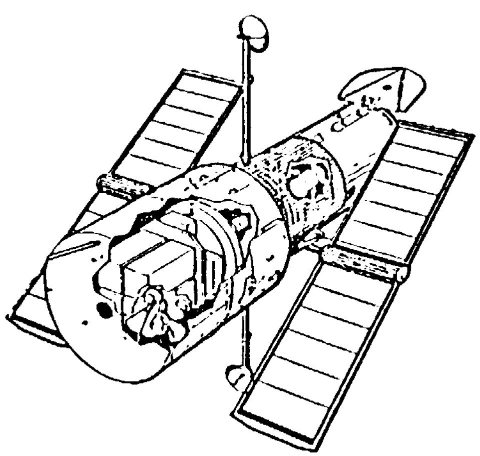
GALILEO



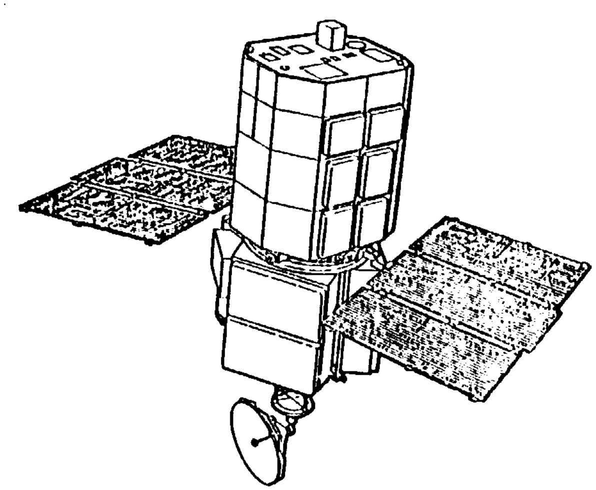
NATIONAL OCEANIC
SATELLITE SYSTEM
(NOSS)



COSMIC BACKGROUND
EXPLORER (COBE)



SPACE TELESCOPE



SOLAR MAXIMUM MISSION

ORIGINAL PAGE IS
OF POOR QUALITY

LOCATION OF PLANNED SATELLITES

The future space missions, including classified military, have been grouped by operational orbit. The quantities of missions at each inclination and altitude are shown.

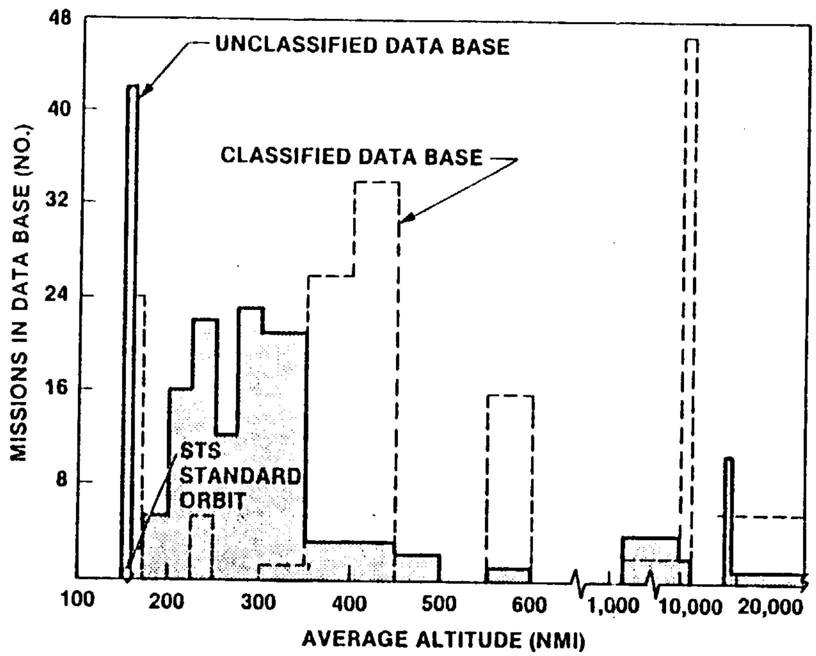
It is evident that the majority of satellites operate above the STS standard orbit. However, this does not necessarily negate revisit servicing. The S^3 can include Teleoperator Maneuvering System (TMS's) and Orbit Transfer Vehicles (OTV's).

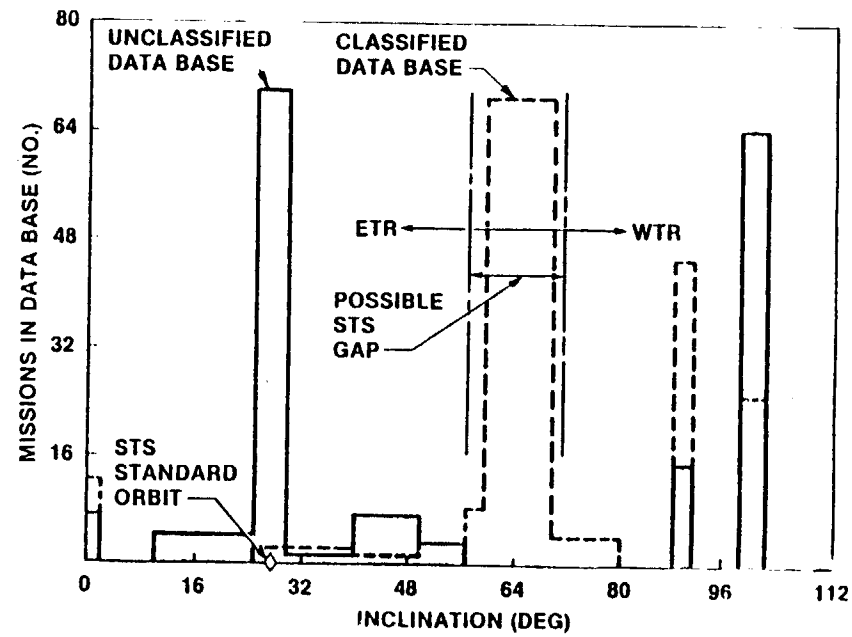
- TMS - Carried by Orbiter; flies from STS standard orbit to the satellite, retrieves it, and returns to Orbiter. After servicing, the Satellite is returned to its operating orbit.
- OTV - This larger propulsion stage has propellant capability to transfer from LEO to GEO and return. It carries spare modules for satellite repair and a module exchange mechanism. It flies to the satellite, docks and makes repair and returns LEO orbiter-accessible orbit. A variant of this mode provides for the OTV to return the satellite to the Orbiter for repair.

Inclination changes can also be made by the OTV. It most cases, satellites are placed in orbit planes that are accessible by the Orbiter.

A satellite designed with its own propulsion capability to take it from the STS standard orbit and return would preclude the need for auxilary propulsion capaiblity.

Location of Planned Satellites





FUTURE NASA/COMMERCIAL MISSIONS

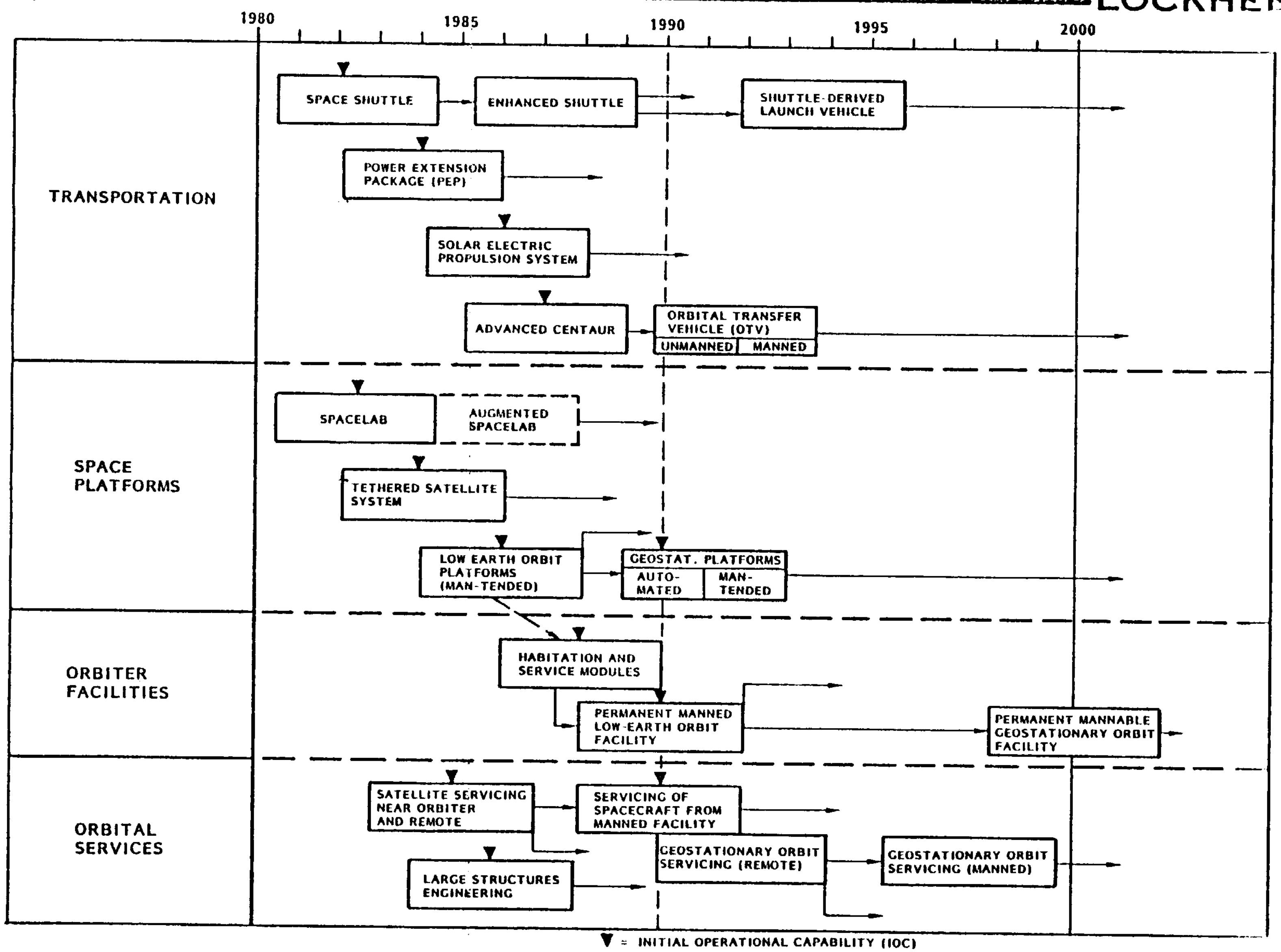
Beyond the currently committed space missions, most of which are science or military oriented, NASA has developed plans for future missions. The chart shows a NASA/HQ scenario for a gradually expanding space effort.

A transition is evident from the smaller science payload satellites to larger vehicles and space platforms primarily oriented to applications or commercial missions.

The Orbiter supplemented by the PEP and 25 KW Power System provides increased on-orbit power to the space vehicles. Upper stages (Advanced Centaur and OTV) provide increased propoulsion to transfer larger space vehicles/equipment to GEO.

Manned operations in space will increase. By 1990 a permanent manned facility, the Space Operations Center will be operational in LEO. This space platform forms the base for the first Space Servicing Depot (defined later).

Future NASA/Commercial Missions



TYPICAL SPACE PLATFORMS

The first manned base, the Space Operations Center, is shown. It is operated in LEO and revisited periodically by the Shuttle for crew rotation and logistic supply. This base accommodates the S^3 Space Depot comprising:

- Servicing Equipment and Service Platforms
- Spares Storage Racks
- Tank Farm for Expendables and Fluid Transfer Modules
- Test/Checkout Equipment
- TMS/OTV Storage
- SPARE ORUs

In 1986 the 25 KW Power System will be available as a free-flyer support spacecraft for a variety of platforms; two of these, are high on the mission-priority list:

Space Processing/Life Science Facility - The initial Life Science Lab Module will be operable by 1986. A Materials Experimentation Module (Space processing) will be added in 1987. A Habitability Module transforms this platform to a manned facility in 1988. Servicing, consisting of experiment and materials supply and exchange, is provided by the S^3.

Large Science/Application Platform - The "initial expandable" unit will be operational in 1986. Structural add-ons and modular paylaods can be added. Pallet-mounted payloads are added, exchanged, or repaired by the Orbiter based S^3.

Typical Space Platforms

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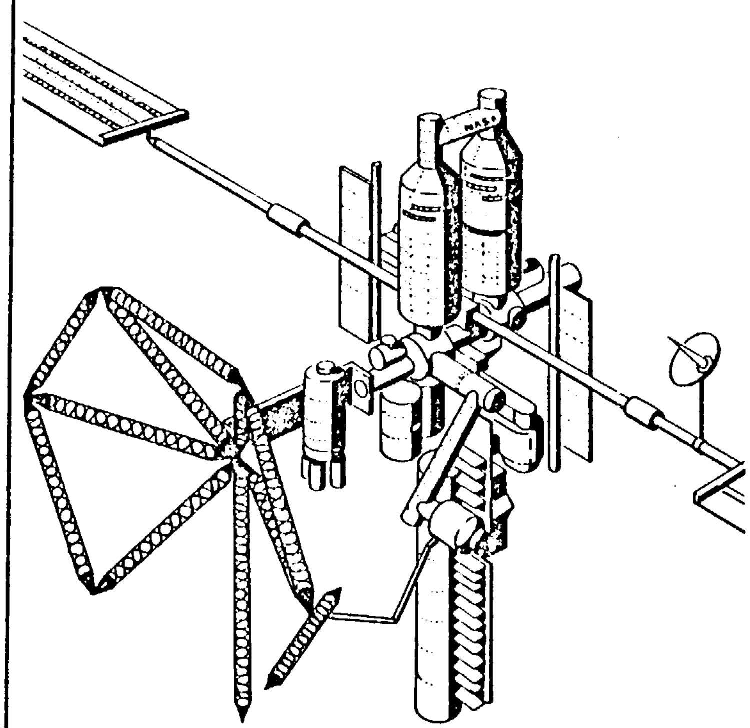
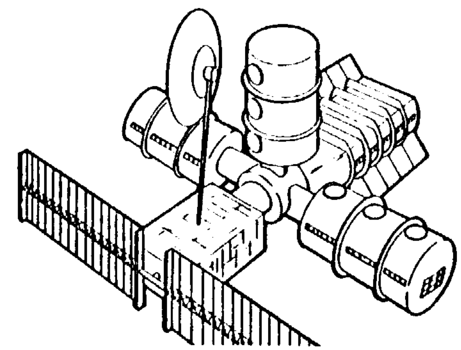
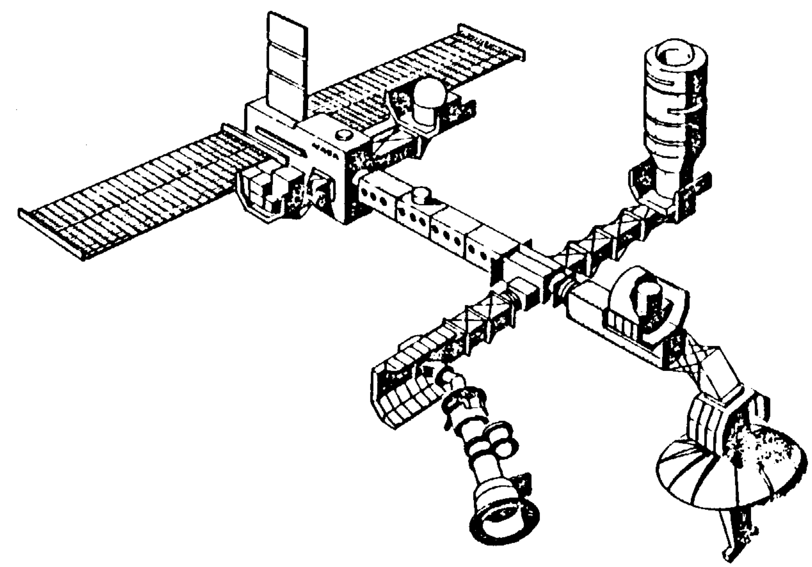


SPACE OPERATIONS CENTER



MULTIMISSION SPACE PROCESSING/
LIFE SCIENCE PLATFORM



LARGE SCIENCE/APPLICATION PLATFORM

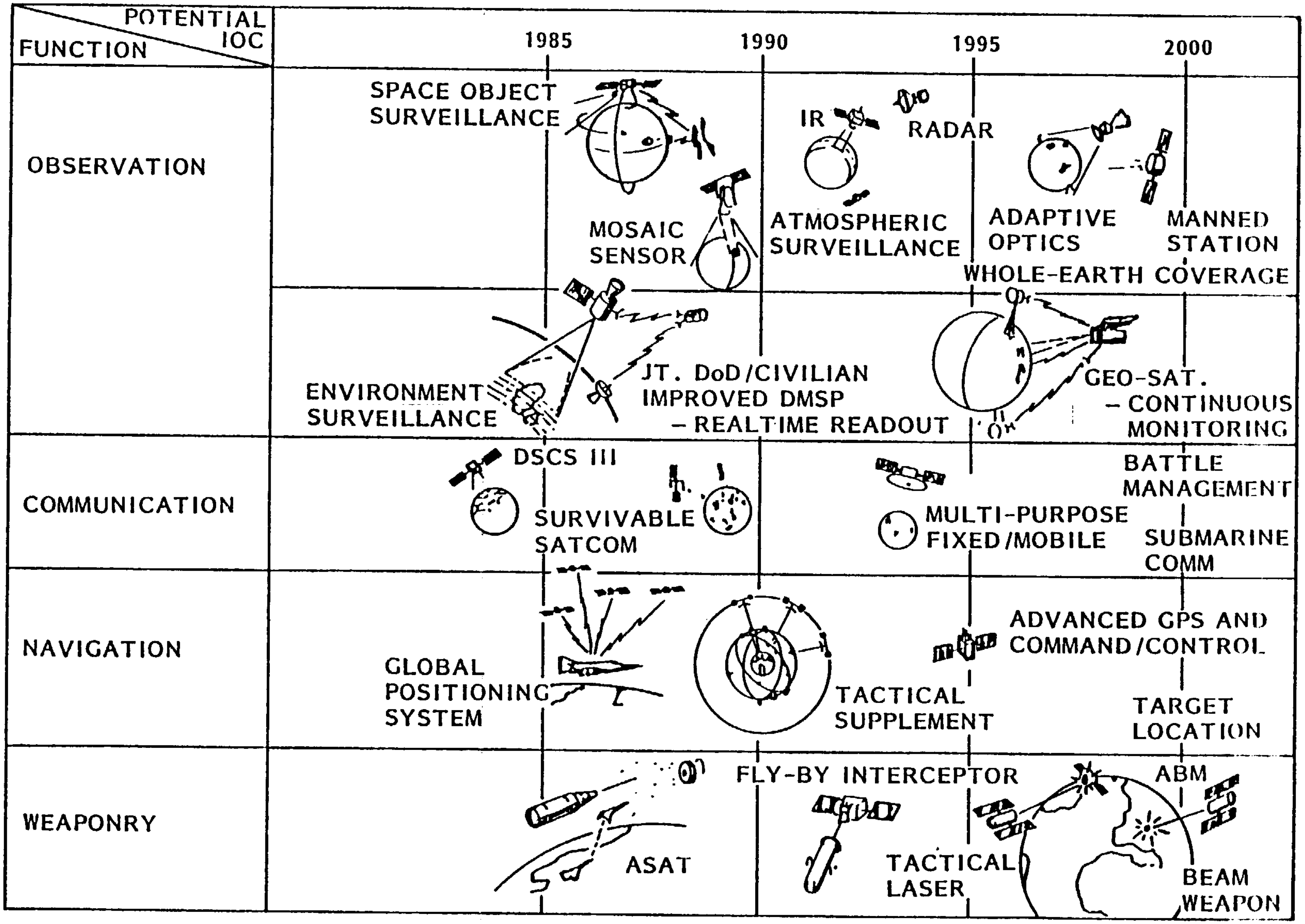
FUTURE MILITARY MISSIONS

The USAF,DARPA and Navy agencies plans for their future space missions in four functional areas are shown here.

The manned-station operational dates appear to lag the NASA planning dates. However, the operation of the NASA space station is expected to accelerate the military appliacation of the technology.

These military missions are included in the total summary of potential customers for S^3.

Future Military Space Missions



NASA

System Description

Lockheed

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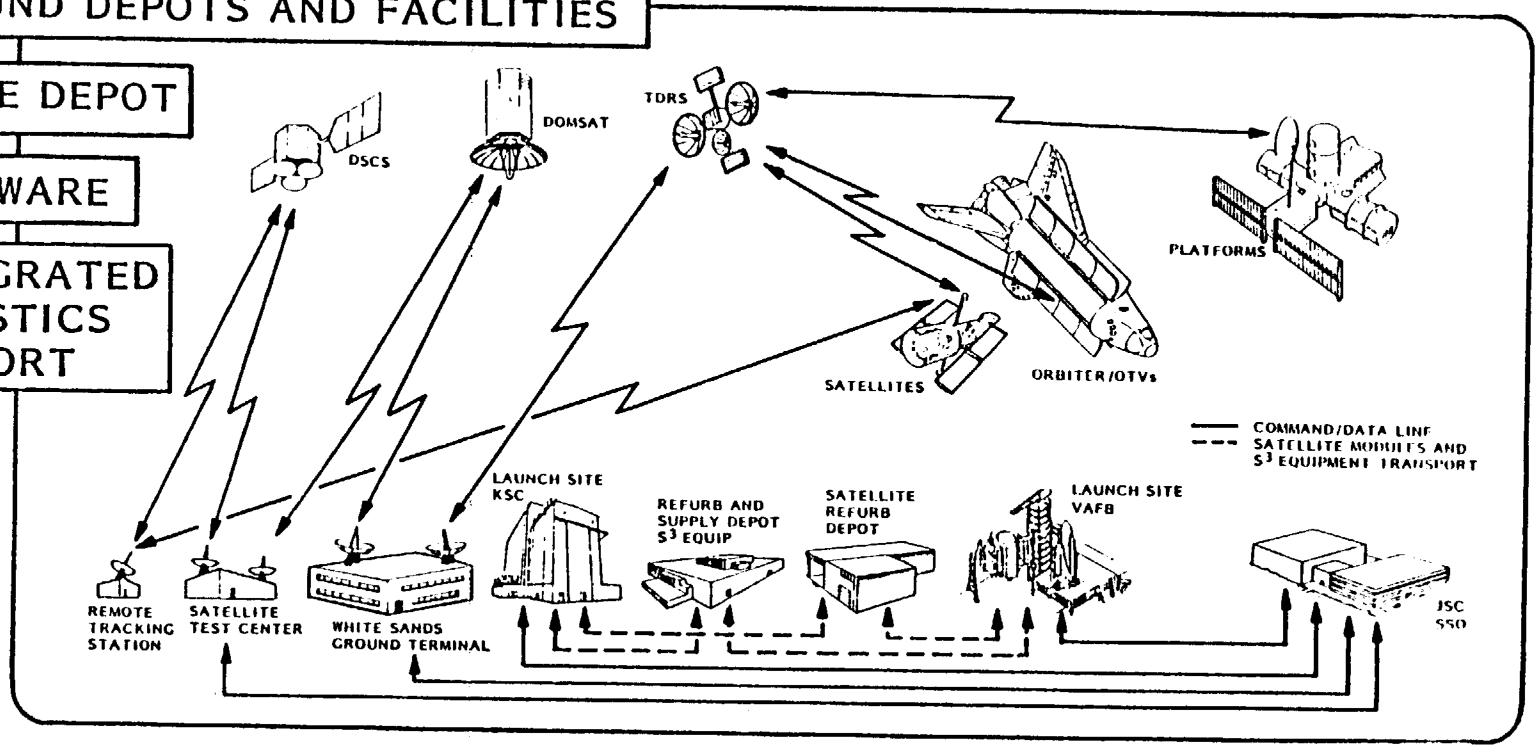
Elements of the S^3

NASA — LOCKHEED

- S^3 SPACE SUPPORT EQUIPMENT
- LAUNCH SITE EQUIPMENT – SPECIAL
- GSE/STE
- SUPPORT VEHICLES
- GROUND DEPOTS AND FACILITIES
- SPACE DEPOT
- SOFTWARE
- INTEGRATED LOGISTICS SUPPORT



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MAJOR HARDWARE ELEMENTS

The elements of the S^3 hardware that are under the cognizance of the Satellite Service Organization (SSO) are listed. The design, manufacture, test, and operation of this hardware is contracted for and by the SSO.

The Space Depot is operated either as an autonomous space base (manned or unmanned) or as an add-on facility to the planned Space Operations Center.

The Ground Depots need not be new facilities, but rather, modifications of assigned areas of current facilities at the launch sites.

The support vehicles, whose primary operational function is to support Satellite Service will be developed under the direction of the SSO.

Major Hardware Elements

SPACE SEGMENT

S^3 SPACE SUPPORT EQUIPMENT

- ORBITER ACCOMMODATION EQUIPMENT
- SATELLITE SERVICEABILITY HARDWARE
- HANDLING/SERVICING/BERTHING DEVICES
- CREW AIDS
- STOWAGE/DEPLOYMENT EQUIPMENT
- EXPENDABLE SUPPLY
- ORBITER I/F EQUIP

SUPPORT VEHICLES

- TELEOPERATOR MANEUVERING STAGE
- MTV
- OTV

SPACE DEPOT

- PROPELLANTS
- LIFE SUPPORT SUPPLIES
- CRYOGENS
- REPAIR MATERIALS
- REPLACEMENT UNITS

GROUND SEGMENT

LAUNCH SITE EQUIPMENT

- SATELLITE SIMULATORS
- ALIGNMENT FIXTURES
- CLEANROOM STORAGE AND KITTING
- KIT ASSEMBLY AND PACKAGING

GROUND DEPOTS

- SATELLITE ORU REFURBISHMENT AND INVENTORY
- S^3 EQUIPMENT REFURBISHMENT AND INVENTORY
- EXPENDABLES SUPPLY

GSE/STE

- TRANSPORT AND HANDLING EQUIPMENT
- SERVICE AND CHECKOUT EQUIPMENT

S^3 KITS AND EQUIPMENT

Six basic types of S^3 equipment are shown. Under each are grouped representative servicing equipment.

The Orbiter Accommodation Hdw comprise S^3 items that are installed in the Orbiter for service missions. Items are specifically manifested for each flight. Commonality adaptability to a wide variety of missions) is fundmental to this system concept to reduce the inventory of different articles performing the same functions and reduce changeout of the orbiter for different missions.

The Satellite Accommodation Hdw is developed as standard supply items (possible GFE); they are supplied to satellite contractors to help meet the requirements for serviceability. Mission- nique variants are minimized.

The expendables resupply equipment comprises an inventory of equipment for transporting propellants, gasses, and other fluids to orbit for replenishment of satellites or tank farms. This becomes an important servicing function as growing quantities of satellites require long-duration operation in orbit.

S^3 Equipment

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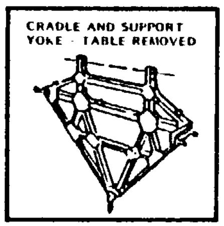
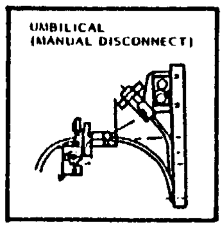
ORBITER ACCOMMODATION KITS

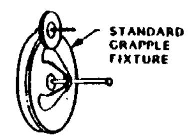
- DISPLAY/CONTROL PANELS (STD)
- UMBILICALS
- I/F HARNESSES AND J-BOXES
- BERTHING/DOCKING MODULES

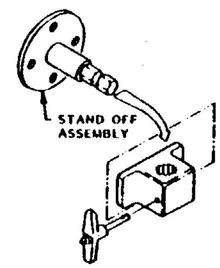

CRADLE AND SUPPORT YOKE - TABLE REMOVED


UMBILICAL (MANUAL DISCONNECT)

SATELLITE SERVICEABILITY KITS

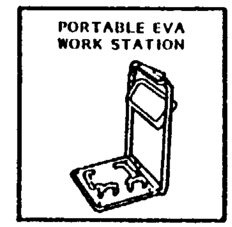
- RMS INTERFACE FITTINGS
- DOCKING TARGETS
- DOCKING/STOWAGE FITTINGS
- RESTRAINT/TETHER RECEPTACLES


STANDARD GRAPPLE FIXTURE


STAND OFF ASSEMBLY

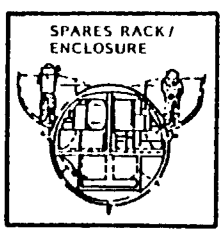
HANDLING/SERVICING MODULES

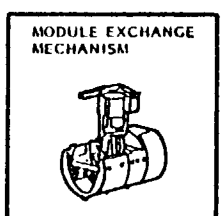
- SATELLITE CHECKOUT SETS
- RMS
- SPECIAL END EFFECTORS
- WORK PLATFORMS
- DESPIN DEVICES


PORTABLE EVA WORK STATION

STOWAGE/DEPLOYMENT EQUIPMENT

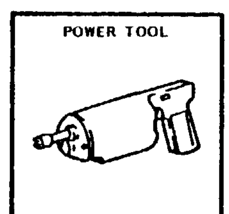
- PALLETS
- SPARES RACKS
- SPECIAL RACKS
- BULK CARGO TIEDOWNS


SPARES RACK/ ENCLOSURE


MODULE EXCHANGE MECHANISM

CREW AIDS

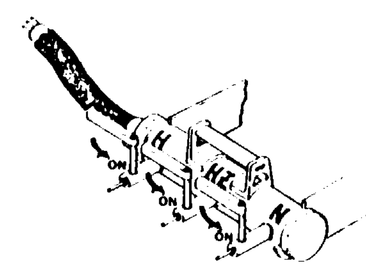
- HAND TOOLS
- MMU
- TETHERS/RESTRAINTS


POWER TOOL


SELF-TENDING TETHER

EXPENDABLES RESUPPLY EQUIPMENT

- TANK KITS
- VENT/DUMP KITS
- FLUID TRANSFER MODULES



S^3 SUPPORT VEHICLES

To ensure an integrated space servicing effort, it is planned that special support vehicles such as those shown will be a part of the S^3 equipment inventory. These space vehicles perform space servicing operations exclusively.

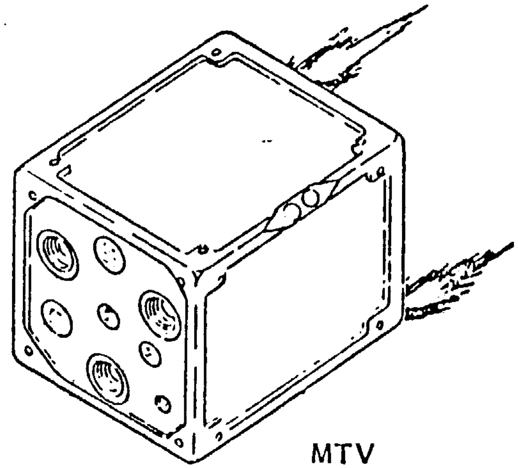
The maneuvering stages are used to retrieve satellites from remote locations and return them to the orbiter. After the satellites are serviced they are returned to their operating orbits. The propulsion stages are refueled from S^3 expendable tankage, also carried by the Orbiter.

The teleoperator stage flies to a remote satellite and exchanges satellite modules. Docking with the satellite and module exchange is accomplished automatically with TV monitoring from the Orbiter. Man-in-loop remote control can be substituted for the automated functions or be used as backup mode.

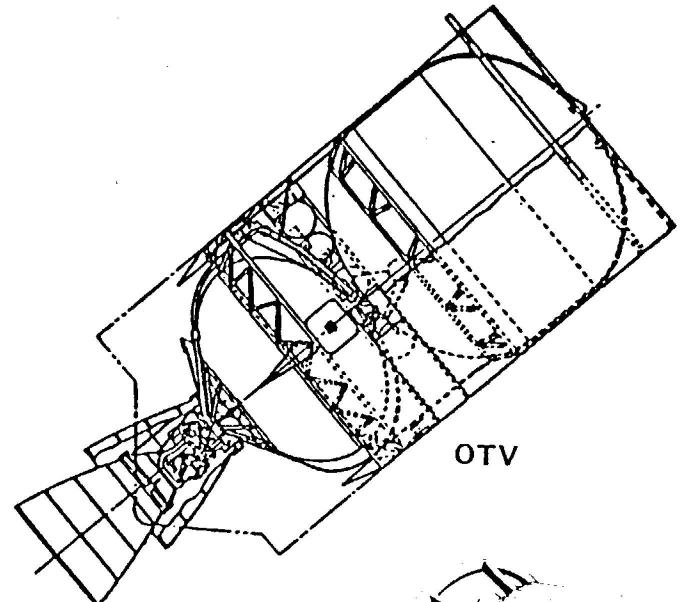
The teleoperator can be mounted on the Maneuvering Stage to obtain greater range of remote operations.

For short-range remote operations with satellites or platforms, where servicing tasks require manipulation with closeup man-in-loop, a small Manned Tug is planned. As operational confidence improves, this manned capsule can be mounted on an OTV for servicing round trips to GEO.

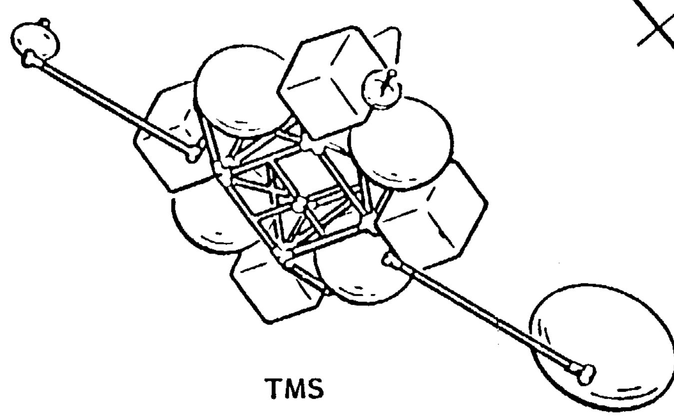
S^3 Support Vehicles



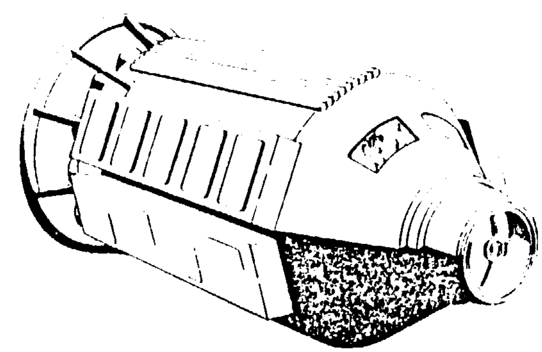
MTV



OTV



TMS



MOTV

GROUND DEPOTS/FACILITIES

The ground based depots and facilities identified in the course of the study are listed here.

Ground Depots/Facilities

- INTEGRATED LOGISTICS SUPPORT FACILITY
  - S^3 EQUIPMENT REFURBISH/SUPPLY DEPOT
- SATELLITE ORU SPARES REPAIR/REFURBISHMENT DEPOT
- SATELLITE SERVICES OPERATIONS CONTROL CENTER
- S^3 DATA PROCESSING FACILITY

SPACE DEPOT (SOC)

An S^3 Space Depot is a natural extension of the Orbiter-based mode of space servicing. As the on-orbit inventory grows, the servicing load will eventually exceed the capability of the STS to meet the demands. Further, the transport up and down of S^3 equipment reduces the net payload capacity on each flight. The storage of the servicing equipment and resupply expendables on an orbiting Space Depot provides added servicing capabilities and cost-reduction benefits.

The Space Depot in concept can be unmanned, with automated equipment monitored with override remote control from the Orbiter and/or from a ground-based control station. The basic approach , however, is to develop a manned depot, with crew performing the servicing function using TV remote-control and EVA operations. This Space Depot can be an autonomous platform; however, to gain the benefits of sonsolidated operations, the Depot is conceived as a major segment of the Space Operations Center (SOC).

The common use of S^3 equipment, both on the Orbiter and on the Space Depot, is made a design requirement in developing the equipment. The transition from Orbiter to Space Depot based servicing can thereby be straight forward growth of capability.

Space Depot (SOC)

- S^3 EQUIPMENT COMPLEMENT*
  - ASSEMBLY/SERVICING PLATFORM
  - CHECKOUT SETS
  - EXPENDABLES AND TANKAGE
  - HANDLING EQUIPMENT
  - STORAGE RACKS
  - ORU REPAIR
  - FLUID TRANSFER KITS
  - TMS
  - DOCKING HANGAR FOR OTV, TMS

- SERVICING OPERATIONS
  - SATELLITE REPAIR (TMS RETRIEVAL AND REDEPLOYMENT)
  - ASSEMBLY AND CHECKOUT OF MULTI-STAGE VEHICLES (PLANETARY AND GEO)
  - REPLENISHMENT OF FLUIDS FOR OTV, TMS, SATELLITES
  - STORAGE AND MAINTENANCE OF OTV, TMS

*INSTALLED ON MANNED SPACE PLATFORM, SPACE OPERATIONS CENTER, OR EQUIVALENT.

S^3 SOFTWARE

Software for the S^3 operation is developed in parallel with the design of the S^3 equipment and the GSE/STE.

The cognizance for software integration resides in the S^3 System Engineering and Integration function. Requirements are closely coordinated with the Operations Control Center organization to ensure workable interfaces with the existing ground networks and the space communication networks (TDRS, STDN, USAF-SGLS).

Prototype software is used during the development testing and space operations simulation.

S^3 Software

- ORBITER INTERFACE SOFTWARE
  - REMOTE CONTROL OF SPECIAL RMS
  - REMOTE CONTROL OF MTV
  - SATELLITE CHECKOUT
  - TMS CONTROL
- S^3 MISSION CONTROL – COMMAND AND TELEMETRY SOFTWARE*
  - REPROGRAMMING
  - DATA ANALYSIS PROGRAMS (SATELLITE CHECKOUT)
  - DATA REDUCTION (FAILURE DIAGNOSIS, SATELLITE STATUS)
- COMMUNICATION INTERFACE SOFTWARE
  - JSC
  - STC
  - POCC (PAYLOAD OPS CONTROL CTR)

*SUPPLEMENTS NORMAL ORBITER AND SATELLITE MONITOR AND CONTROL

NASA

Work Breakdown Structure And Schedule

Lockheed

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S^3 PLACEMENT IN STANDARD SPACE SYSTEM WBS

The WBS shown in this chart indicates where satellite services is placed in the standardized WBS for Space Systems that has been developed by the Standardization Subgroup of the joint Government/Industry Space Systems Cost Analysis Group.

S^3 Location in Standard Space System WBS

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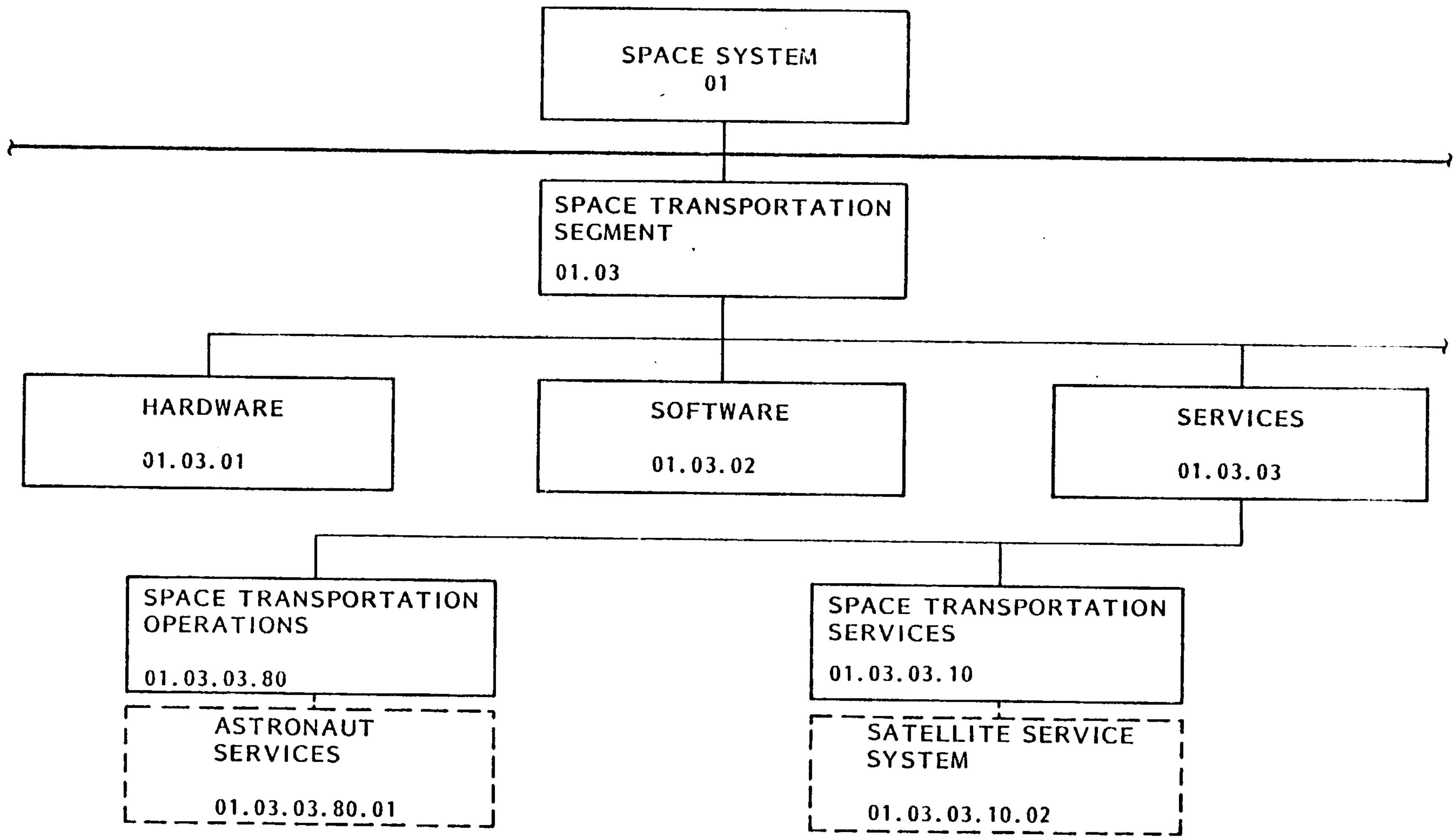


TOP LEVEL S^3 WBS

This chart shows the top-level Satellite Services functions and cost accumulation blocks.

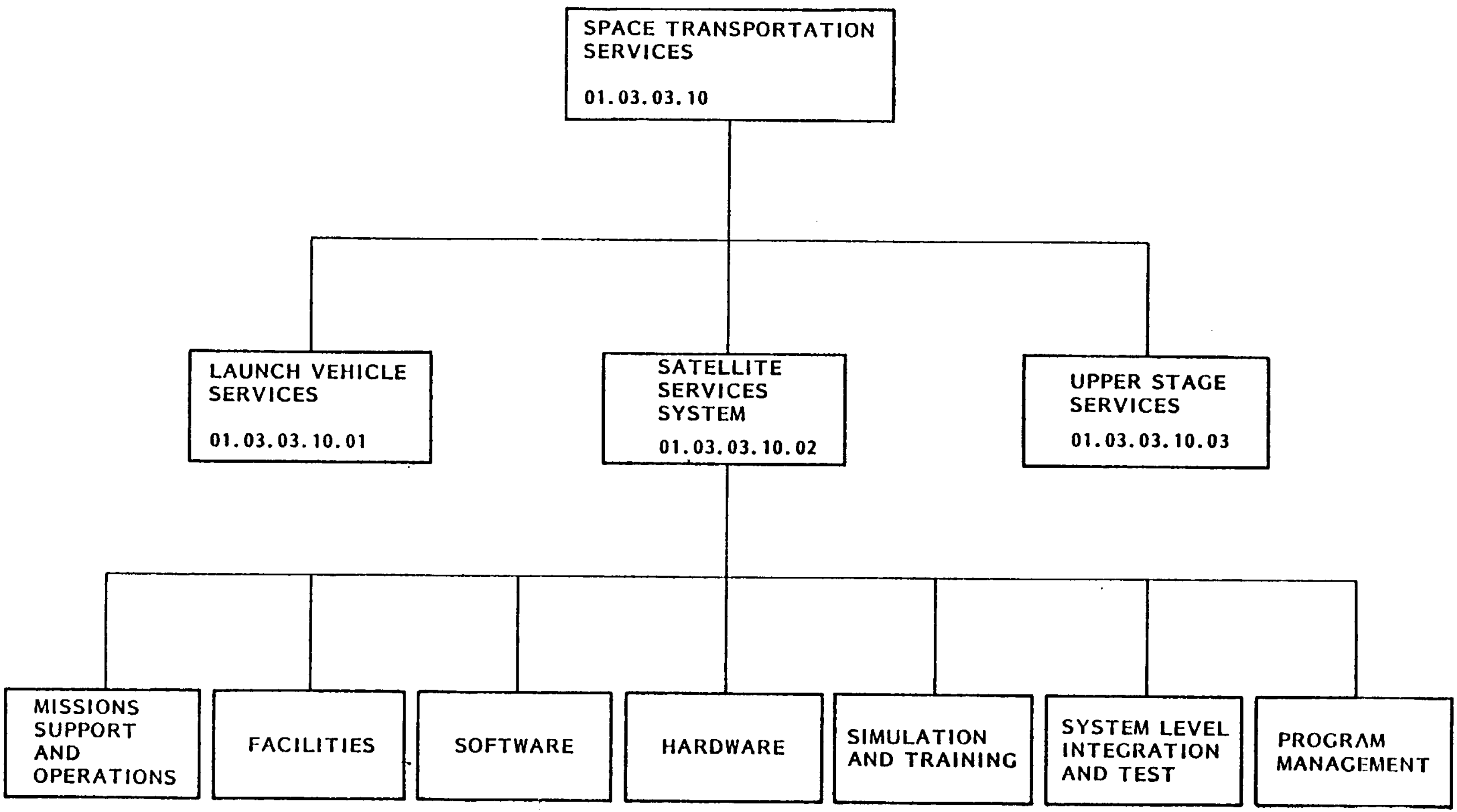
The standardized Work Breakdown Structure (WBS) has been developed by the Standardization Subgroup of the joint Government/industry Space Systems Cost Analysis Group. This WBS features a common 4-level structure that applies to all phases of a space system's life cycle. This framework is designed to be tailored in both the end-item and time-phasing dimensions so as to create specific project work breakdown structures that match the programs being procured. In general, levels 1 through 3 are fixed; levels 4 and below are used to implement this tailoring. The philosophy of WBS tailoring may be summarized as follows:

- o End-item tailoring is normally accomplished by expanding the WBS blocks for subsystem-level hardware, software and services. However, limited end-item tailoring can also be done at segment level when special circumstances warrant.
- o Tailoring in the time-phasing dimension (to distinguish RDT&E, produciton, and O&S phases) is accomplished by deleting WBS blocks that do not apply to the instant phase of a program.

Those end-item codes that end in zero (e.g., 10, 20) flag WBS blocks in which program peculiar tailoring of hardware, software, and services is normally expected. These blocks are to be expanded with appropriate subsystem and lower level end-item breakdowns.

This standard WBS is end-item oriented; that is, it deals with the dimension of program resources that result in a definable and product or service. The other dimensions of program cost; i.e., subdivisions of work and elements of cost, have not been standardized because they tend to be peculiar to each user.

Top Level S^3 WBS



2-7

SATELLITE SERVICE SYSTEM WBS

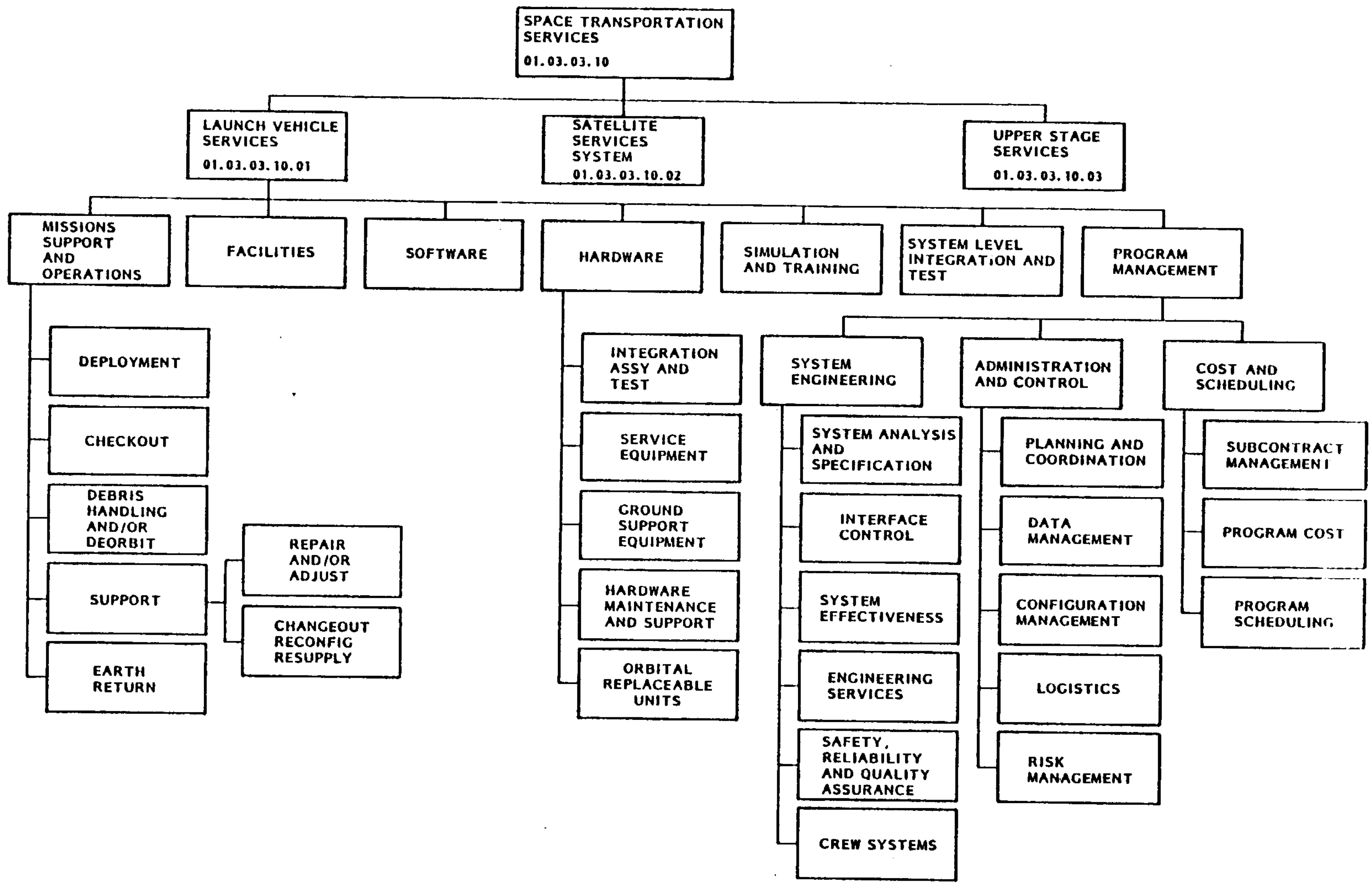
TYPICAL SUBDIVISIONS OF WORK

Design/Analysis
Fabrication and Assembly
Quality Assurance
Test
Tooling and Manufacturing Test Equipment
Administration

TYPICAL ELEMENTS OF COST

Labor Hours
Materials
Subcontracts
Computer Hours
Interdivisional Work Orders
Travel
Reproduction
Overtime Premium
Overhead
General and Administrative Cost
Other Burdens
Temrination Charges
Other Direct Charges
Fee

Satellite Service System WBS



DEVELOPMENT PHASE WORK ITEMS

Each "X" in the matrix indicates which type of effort accomplished in the corresponding Development Phase.

Development-Phase Work Items

WBS ELEMENT	PRELIMINARY PLANS	PRELIMINARY ANALYSES	PRELIMINARY DESIGN FLIGHT EQUIPMENT	TEST ARTICLE DESIGN	SIMULATOR DESIGN	TEST ARTICLE AND SIMULATOR MFG	TESTING AND SIMULATION
PROGRAM MANAGEMENT	X						
SYSTEM-LEVEL INTEGRATION AND TEST	X	X		X	X		X
HARDWARE	X	X	X	X	X	X	
SIMULATION AND TRAINING	X	X		X	X		X
MISSION SUPPORT AND OPERATIONS	X						
FACILITIES	X						
SOFTWARE	X	X	X	X			X

CANDIDATE SERVICEABLE MISSIONS

Typical missions in each of four categories are shown. The significant feature of these planned launch dates is the potential need for S^3 support as early as 1982.

NASA — LOCKHEED

Candidate Serviceable Missions

LAUNCH DATES

CY	81	82	83	84	85	86	87	88	89	90
SORTIE										
OSTA-1		▼								
OSS-1		▼								
SPACELAB-1			▼							
GEOSYNC										
TDRS-A/IUS-2		▼								
TELESAT-A/SSUS-D		▼								
INTELSAT-A/SSUS-A		▼								
PLANETARY										
GALILEO ORBITER/IUS-3				▼						
SOLAR-POLAR/IUS					▼					
LEO										
SPACE TELESCOPE				▼						
LDEF				▼						
GRO					▼					
EUVE					▼					
ADVANCED MISSIONS										
LARGE DEPLOYABLE ANTENNA					▼					
SEPS						▼				
25 kW POWER SYSTEM						▼				
MEC (M&P EXPER.)						▼				
SCIENCE/APPL. PLATFORM						▼				
OTV (GEO)								▼		
GEO PLATFORM (EXPER.)								▼		
SOC CORE PLATFORM								▼		
MANNED OTV									▼	

NASA

System Integration Approach

Lockheed

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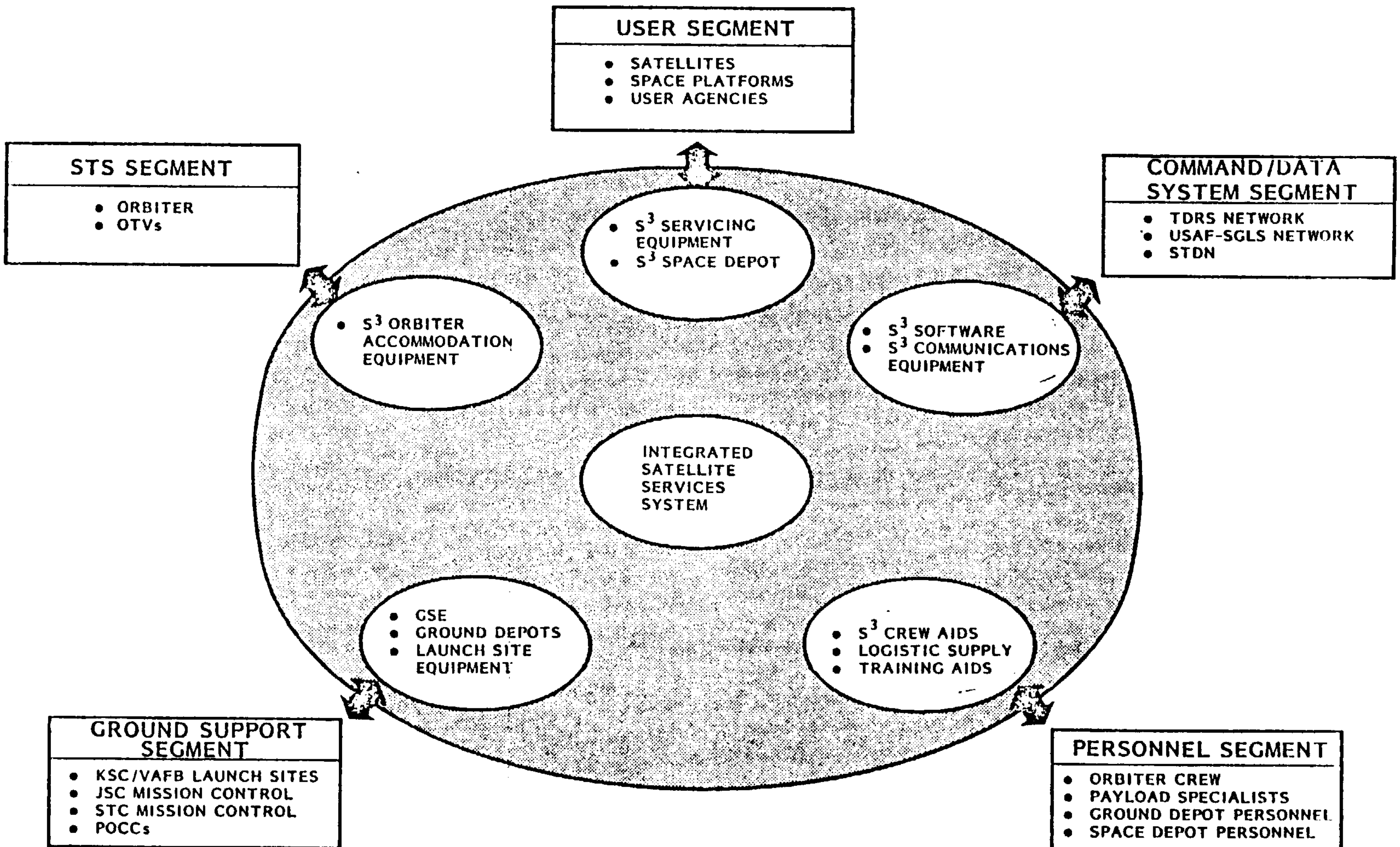
INTEGRATED HARDWARE/SOFTWARE

This plan emphasizes an "integrated" servicing system. Five basic segments are identified as interfacing with the S^3.

The central management of the S^3 establishes the working interface with each external segment and defines the associated hardware/software to ensure a composite system which supports all satellite service users.

Integrated Hardware/Software



SYSTEM-LEVEL INTEGRATION & TEST
S^3 EQUIPMENT

The test and integration flow for S^3 equipment is shown.

The qualification articles are subject to factory tests F-2 thru F-5. Each qualification item is refurbished and becomes the first flight article.

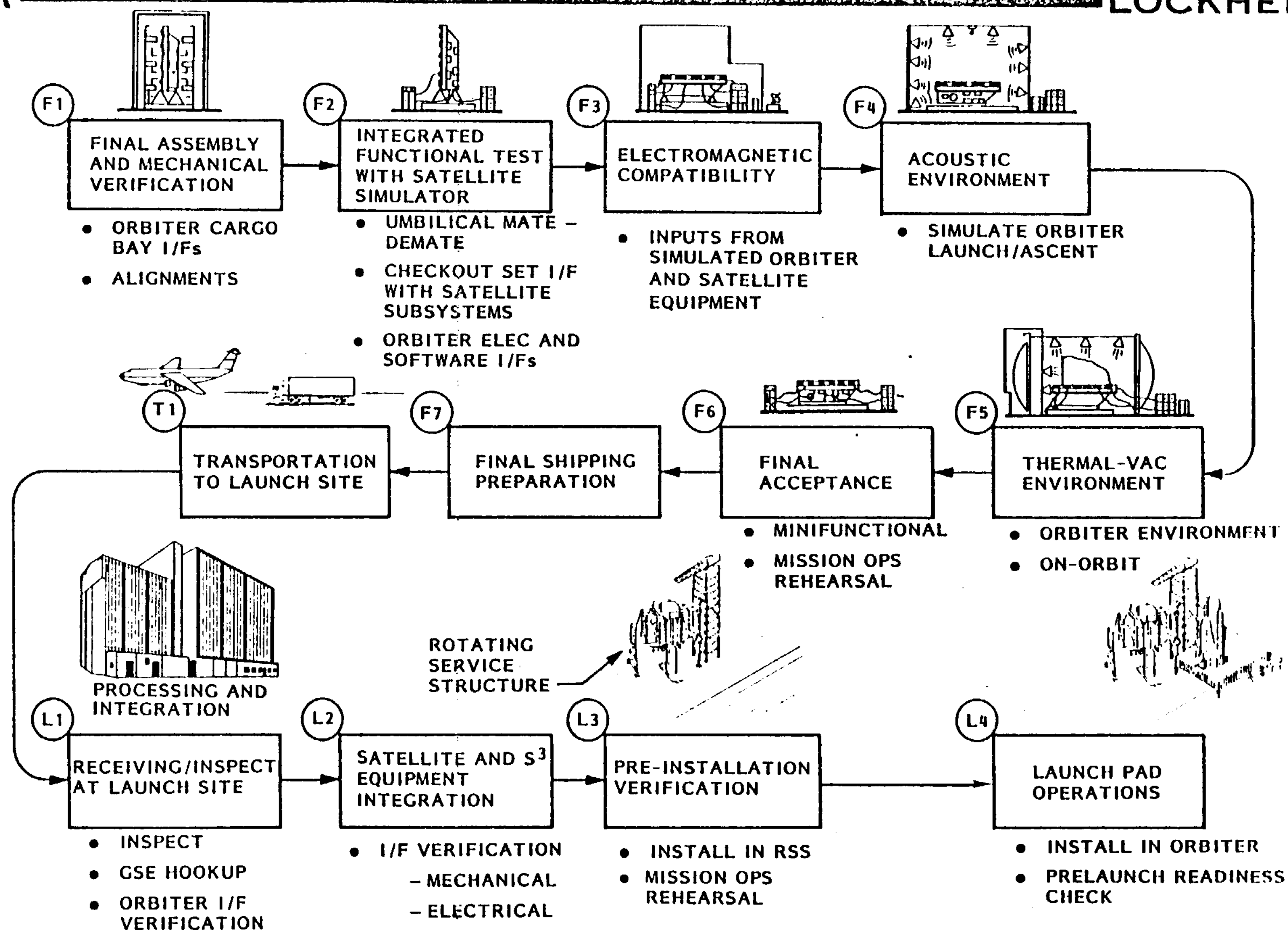
All flight articles are processed thru F-1, F-6, F-7 at the factory before transfer to the S^3 Supply Depot at the launch site.

S^3 Kits, selected for each Shuttle flight and satellite mission, are processed through Systems L-1 thru L-4.

The integration and testing of each mission kit is planned in detail by the Systems Engineering Organization.

System Level Integration and Test
S^3 Equipment

NASA — LOCKHEED



S^3 CREW INTEGRATION

Crew operations have a major influence on efficient servicing. All space servicing operations require crew participation, either man-in-loop remote control of equipment or direct hands-on activity in EVA mode.

Crew training includes rehearsal, to maximum extent possible, of orbit operations. Such rehearsals are conducted in simulated orbit conditions at various levels of reality.

All S^3 crew activities and training are coordinated by a group within the S^3 management team.

Crew considerations have a primary impact on organization and operation of the Satellite Service Operations Control Center (SSOCC). These include the ground monitoring of service operations and the processing of commands to the S^3 crew and equipment.

S^3 Crew Integration

CREW SYSTEMS ENGINEERING

- CREW SAT INTEG REQTS
- CREW SUPPORT I/F AND INTEG REQUIREMENTS
- STS – PAYLOAD ICDs/IRDs
- CREW FUNCTION/TASK ANALYSES
- CREW TIMELINE ANALYSES
- PIP INPUTS
- FLT DATA FILE INPUTS
- MOCKUP/SIMULATOR ANAL/INTEG

IN NEAR-ORBITER IV AND EV OPERATIONS

- SAT HANDLING/POSITIONING
- BERTHING/DOCKING
- VISUAL AND CCTV INSPECT
- APPENDAGE OVRD/JETTISON
- CHANGEOUT
- RESUPPLY AND REPAIR
- ORU MANIPULATION

REMOTE MAN-IN-THE-LOOP ORBIT OPERATIONS

- SATELLITE GRAPPLING RETRIEVAL
- TMS OPS WITH REMOTE GRAPPLE AND DOCK
- BERTHING SATELLITES AND PLATFORMS TO ORBITER
- REMOTE MODULE REPLACEMENT
- OBSERVATION/CHECKOUT

SATELLITE SERVICE OPS CONTROL CENTER (SSOCC)

- S^3 INTERFACES WITH STS
- S^3 INTERFACES WITH SATELLITES/PLATFORMS
- NETWORK INTERFACES:
  - TDRS
  - STC
  - STDN

CREW TRAINING

- FLT CREW TRNG PROGM INTEG
- SIMULATION PROGM I/F AND INTEG
- MOCKUP/SIMULATOR COORD
- SIMULATION CONDUCT
- VERIFICATION PROGM INTERACT
- DEMONSTRATIONS/FEAS ANAL
- PLANS/PROC DEV/COORD
- DOCUMENTATION I/F

NASA

Major Support Systems And Interfaces

Lockheed

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INTEGRATED OPERATIONS

The principal segments of the S^3 operations are shown on this figure.

S^3 equipment is transported from the supplier to the Supply and Refurbishment Depot where kitting takes place at the launch base.

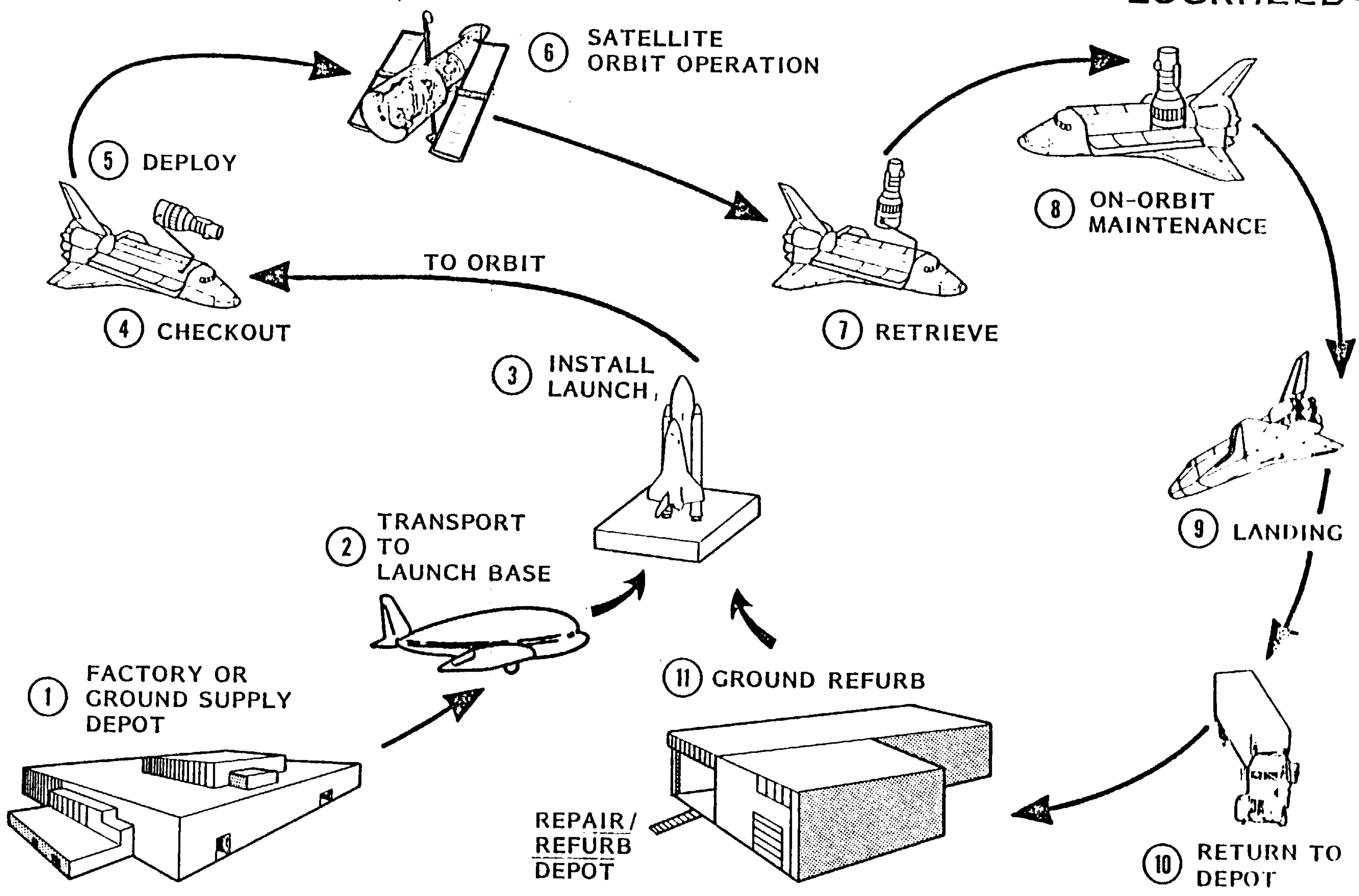
Satellite(s) and S^3 equipment are mounted in the Orbiter and interfaces are verified.

On-orbit, a checkout of the deployment satellite is conducted and if necessary simple fixes are made under direction of the Program Operations Control Center or the Payload Specialist. The Satellite is then deployed and checked again over an RF link to the POCC or Orbiter while in station keeping free flight.

Another satellite may be retrieved for repair or changeout/reconfiguration/resupply and after checkout, is redeployed or returned to earth in accordance with the mission plan.

Upon return to earth, the S^3 equipment is off loaded and sent to the S^3 Supply and Refurbishment Depot.

Integrated Operations



USER INTERFACES

Because the users provide a primary influence on the success of the S^3 program, a strong User's Interface function is planned and maintained. Working groups are developed to cover each of the primary interface areas.

The consolidation of User needs continue with updated requirements and ICDs issued frequently to inform all parties of existing and planned capabilities.

User Interfaces

CONSOLIDATED S^3 USERS

- NASA
- DOD
  - AIR FORCE
  - NAVY
  - ARMY
  - DARPA
- OTHER
  - DOA
  - DOE
  - DOI
- COMMERCIAL
- FOREIGN

S^3 INTERFACE WORKING GROUPS

- SATELLITES AND SPACE VEHICLES
- STS
- GROUND FACILITIES
  - LAUNCH SITES
  - REFURBISHMENT DEPOTS
  - SUPPLY DEPOTS
  - SIMULATION AND TRAINING
- COMMUNICATION NETWORKS
  - TDRS, STDN
  - SCF
- ASTRONAUTS
- FLT CREW
- TEST AND VERIFICATION
- FLT DATA
- AIRBORNE SUPPORT EQUIP
- FLIGHT TECHNOLOGY
- P/L INTEG PLAN

S^3 INTERFACE DOCUMENTS

- S^3 USERS' GUIDE
- INTERFACE CONTROL DOCUMENTS (ICDs)
- P/L ICDs
- P/L IRDs
- PROCEDURES
- TEST/VER DATA
- SIM DATA
- PIP
- FLT DATA FILE
- TRNG PGR PLANS
- OPS/FUNCTIONS DOC
- ORBITER TO P/L ICD
- FLT MANIFEST DATA
- ETC

GOVT/SUPPLIER INTERFACES

With the grosth of space activities as a result of the STS operations, economies procurring and storing of space equipment/supplies are available. The S^3 operation offers an excellent opportunity to consolidate government procurement to realize these economies.

Consolidated buying, rather than procurement of logistic material on a one-at-a-time mission unique basis provides obvious system cost benefits.

Simplification of Government procurement, reduction in paperwork load, the reduction of the logistic supply flow and timelines can result from the consolidaton of service equipment procurement.

NASA — SSS — LOCKHEED

Government/Supplier Interfaces

CENTRALIZED PROCUREMENT OF MATERIAL AND SERVICES TO SUPPORT INTEGRATED LOGISTICS FLOW:

GOVERNMENT PROCUREMENT

- S^3 EQUIPMENT
- SATELLITE SPARE PARTS
- EXPENDABLES RESUPPLY

CONTRACTORS

- S^3 EQUIPMENT
- SPACE VEHICLE SPARES
- EXPENDABLES
  - PROPELLANTS
  - CRYOGENICS
  - LIFE SUPPORT

GOVERNMENT DEPOTS

SATELLITE ORU REFURBISHMENT

SATELLITE SPARES SUPPLY

S^3 EQUIPMENT REPAIR / REFURBISHMENT

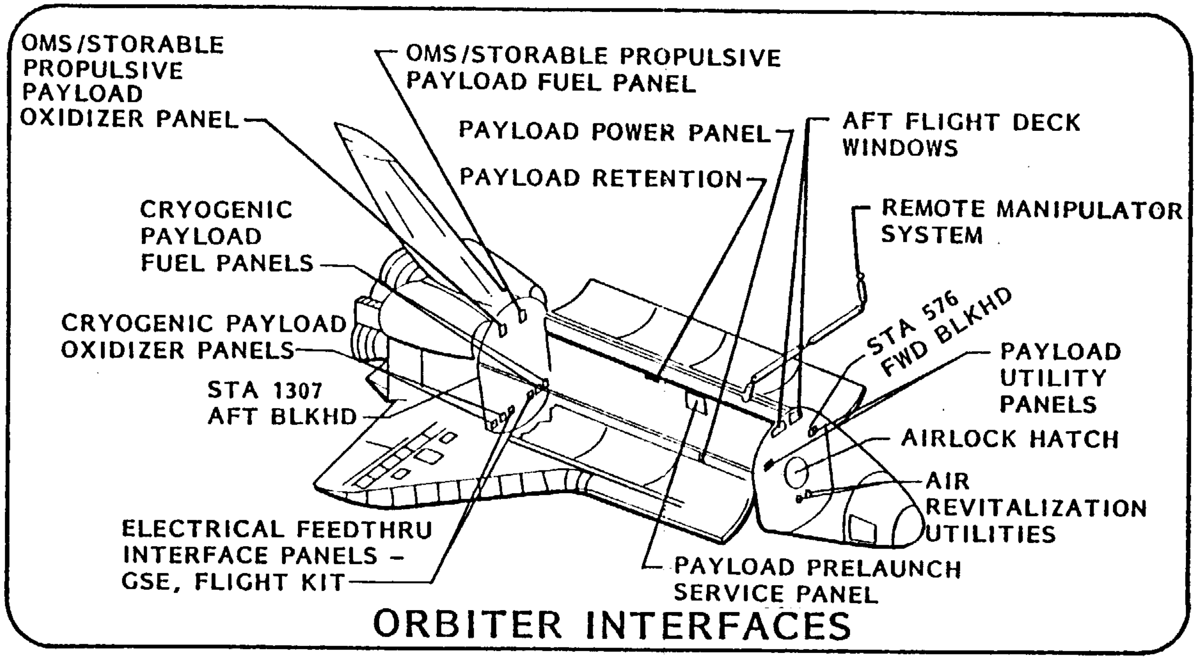
S^3 EQUIPMENT SUPPLY

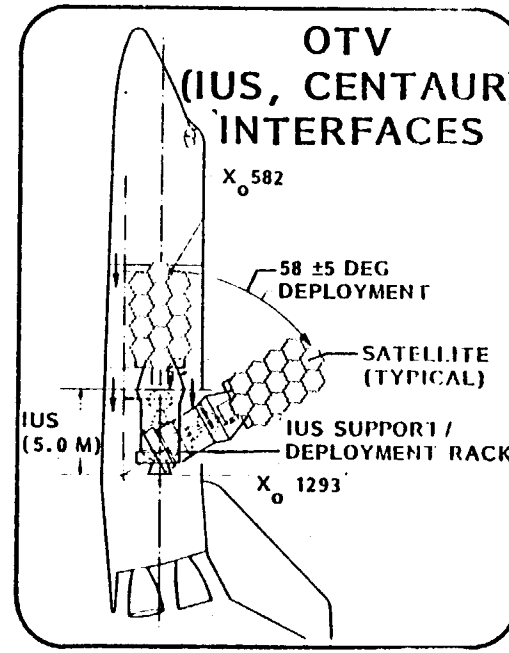
STS INTERFACES

The space segment of the Space Transportation System consists of the orbiter and propulsion vehicles such as IUS and Centaur. As space operations are extended, higher-capability, Orbit Transfer Vehicles (OTV's) will be placed in the STS inventory. The OTV is planned to use cyogenic propellants and be space-refuelable; it is applicable to remote S^3 operations (high-altitude and GEO orbits).

In the early Shuttle launches of IUS/satellite packages, experience is gained which can be applied to in orbit checkout and repair of OTV's as well as attached satellites. The propellant replenishment capabilities are added to the S^3 as the Centaur and hydrazine-fueled TMS are put into service.

STS Interfaces





S^3 ORBITER/OTV ACCOMMODATION KITS

- BERTHING/DOCKING MODULES
- I/F HARNESSES AND J-BOXES
- RMS
- SATELLITE UMBILICALS
- DISPLAY/CONTROL PANELS
- I/F SOFTWARE
- TV CAMERAS/LIGHTS

S^3 COMMUNICATIONS NETWORK INTERFACES

One of the principal functions of the Satellite Service Organization is to plan, coordinate, and prepare schedules for use of the NASA and DoD communications networks. The SSOCC implements these tasks.

The SSOCC is located on the JSC site to assure close interfacing with STS Mission Control.

A separate SSOCC contingent may be located at the USAF STC for DoD missions.

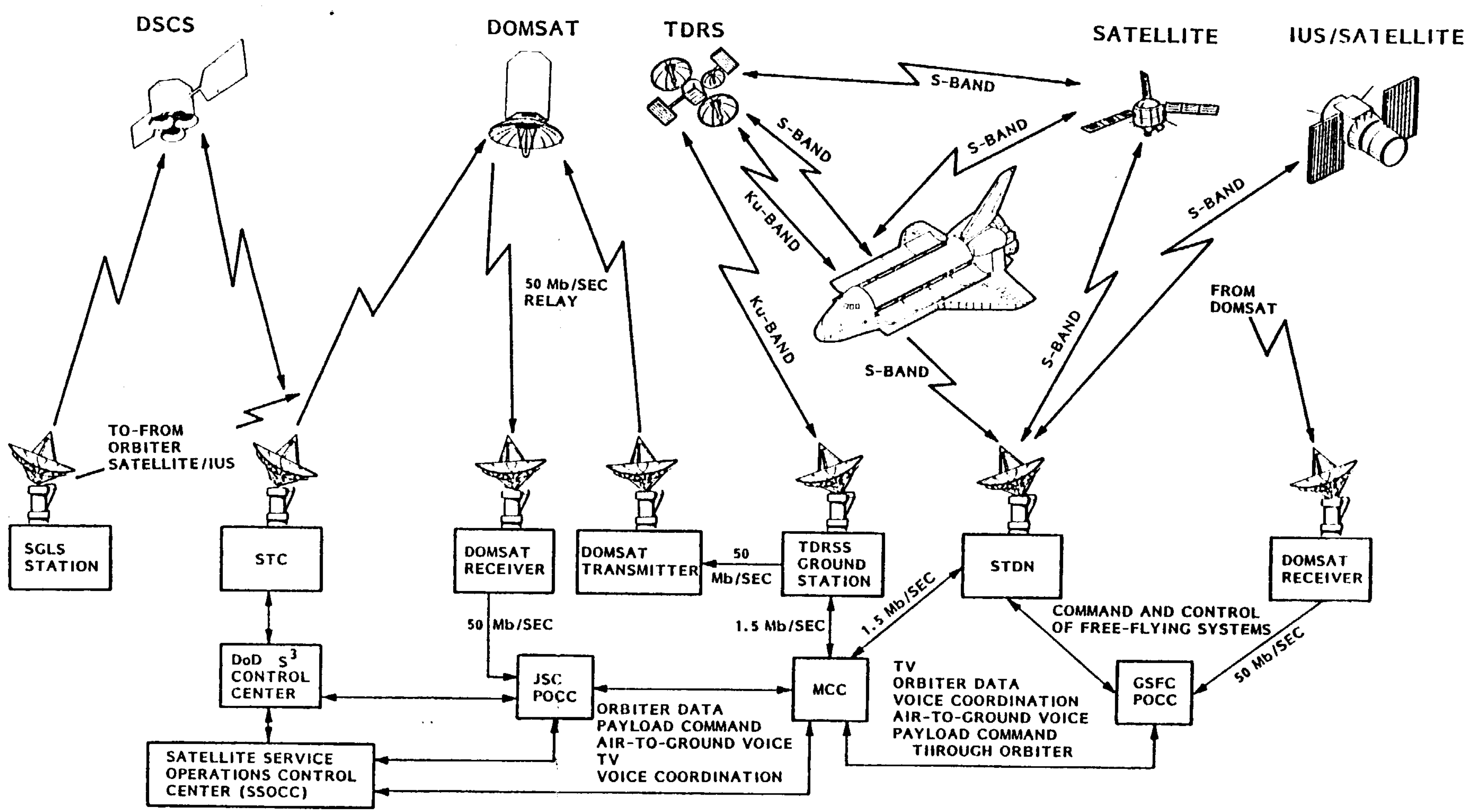
DSCS = Defense Satellite Communications System (DoD)

SGLS = Space Ground Link System (USAF)

STDN = Space Tracking and Data Network (NASA)

TDRS = Tracking and Data Relay Satellite (NASA)

S3 Communication Network Interfaces



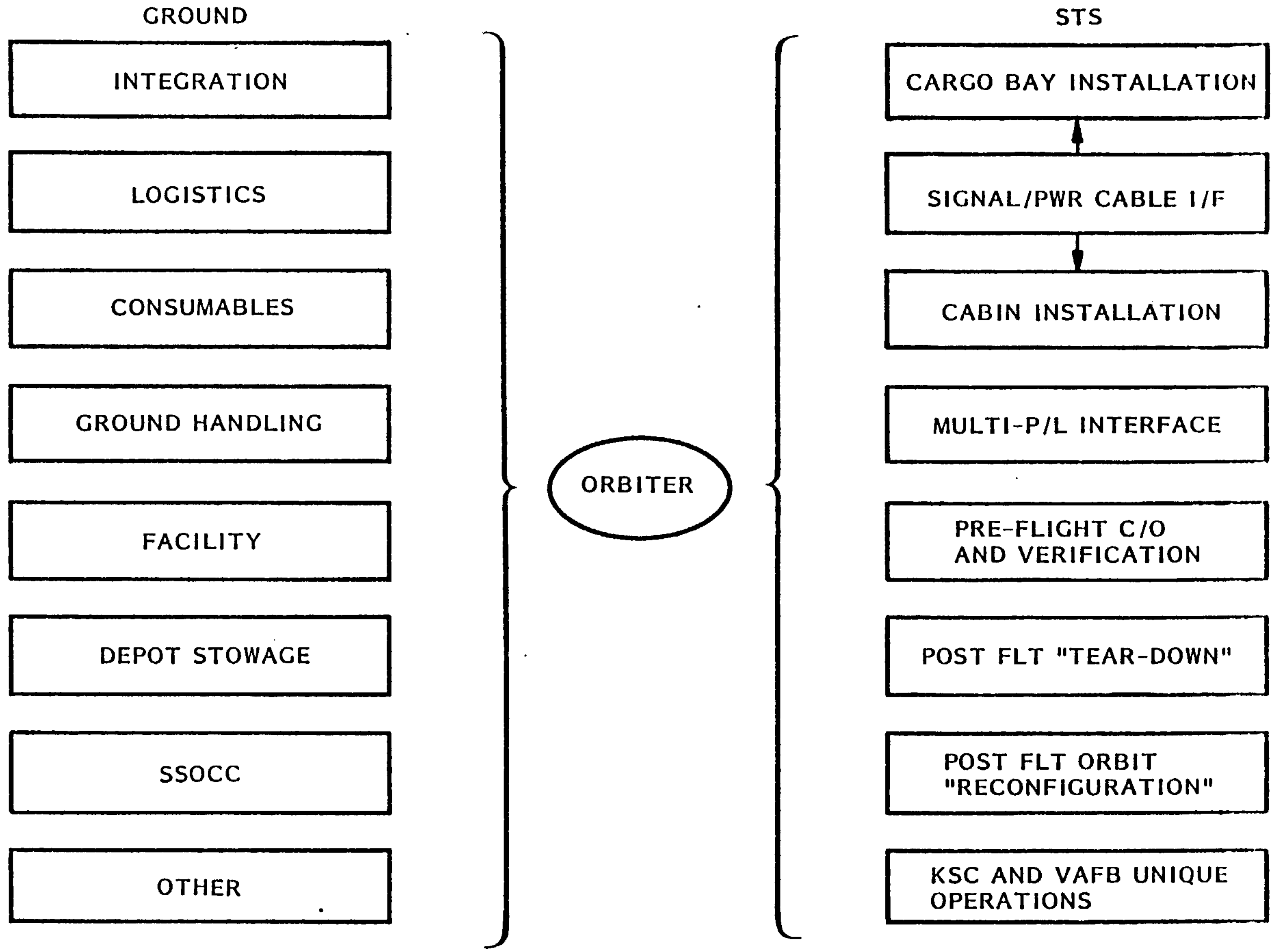
S^3 GROUND SUPPORT INTERFACES

The Satellite Service System ground operations have significant interfaces with the Space Transportation System ground segment. The S^3 flight hardware and consumables require preflight installation and post flight removal from the orbiter cargo bay. All power and signal interfaces of the S^3 equipment, the orbiter, and the payloads require operations planning and checkout consoles.

The integrated logistics flow of the STS is impacted by but to a large extent dictates the S^3 supply depot activities in order to maintain the flight scheduling.

The flight support of the S^3 operations (the SSOCC) is organized for close cooperation with the launch base control, JSC mission control and the Program Office operations centers.

S^3 Ground Support Interfaces



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GSE/STE

The S^3 equipment is supported by its own Ground Support Equipment and Special Test Equipment. This hardware is developed in parallel with the S^3 equipment.

The function of the GSE is to support, store, handle, transport, and inspect/align/weigh S^3 equipment during manufacture, test, launch preparation, and depot operation.

The function of the STE test support during development, qualification, factory acceptance, and prelaunch verification, and depot testing.

The appropriate GSE/STE which exists in Government inventory is used where possible in the S^3 program.

Multiple quantities of the GSE/STE are required to support S^3 operations at two launch bases and any remote depot or supply locations.

GSE/STE requirements is managed by the SSO to ensure maximum application of common GSE/STE.

GSE/STE

SUPPORT INITIAL-DELIVERY S^3 KITS, SPARES, AND REPAIR/REFURBISHMENT OPERATIONS AT DEPOTS

- GSE
  - SHIPPING/STORAGE CONTAINERS
  - PROTECTIVE COVERS
  - STORAGE RACKS/PALLETS
  - ASSEMBLY/SUPPORT STANDS
  - DOLLIES/TRANSPORTERS
  - HANDLING SLINGS
  - WT/CG SUPPORT FIXTURE AND MEASUREMENT EQUIPMENT
  - ALIGNMENT FIXTURES AND GAGES
  - MASS SIMULATORS
- STE
  - TEST COMPUTER
  - MONITOR CABLE SETS
  - TEST CONSOLES
  - CHECKOUT SETS
  - ACOUSTIC, VIBRATION TEST SUPPORTS
- GFE
  - AIRCRAFT LOADING FIXTURE – C5A
  - SATELLITE I/F SIMULATORS
  - STDN I/F TEST VAN
  - SATELLITE MASS/SIZE SIMULATORS
  - IUS FUNCTIONAL I/F SIMULATOR
  - CENTAUR FUNCTIONAL I/F SIMULATOR
  - ORBITER FUNCTIONAL I/F SIMULATOR
  - ORBITER MECHANICAL SIMULATOR (CARGO BAY)

MANUFACTURING/ TEST SITES | LAUNCH SITES | REPAIR/ REFURBISHMENT DEPOT | SUPPLY DEPOT

Facilities

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S^3 FACILITIES

The facilities required for manufactuing/test and subsequent operation of the S^3 are shown here. In general, all brick and mortor facilities are in existence. In some cases, modification is required to adapt to S^3 operations.

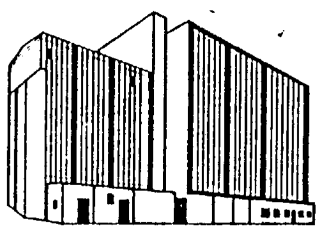
The S^3 Repair/Supply Depot is listed as "new". However, it can be implemented by dedication of specific areas within existing buildings at the launch site. The integration of equipment into kits is performed in this depot.

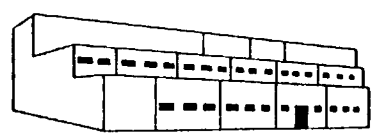
The Satellite Spares Depot can be accommodated in an existing building either off-site or at the launch base.

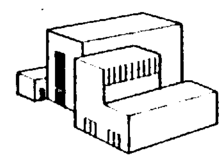
When the VAFB launch site is activated, replication of the KSC S^3 facilities is planned.

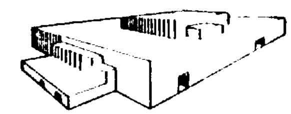
S^3 Facilities

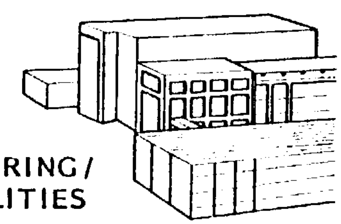
FACILITY	LOCATION	STATUS
S^3 EQUIPMENT REFURBISHMENT/SUPPLY DEPOT	LAUNCH SITE	NEW
ORU REFURBISHMENT AND SPARES DEPOT	OPTIONAL	NEW
EXPENDABLES SUPPLY DEPOT	LAUNCH SITE	MODIFIED
MOCKUP/SIMULATION/TRAINING	JSC	MODIFIED
LAUNCH ASSEMBLY/TEST	KSC/VAFB	EXISTING
MANUFACTURING TEST (CONTRACTORS)	VARIOUS	EXISTING
S^3 MISSION CONTROL AND DATA PROCESSING	JSC/STC	MODIFIED

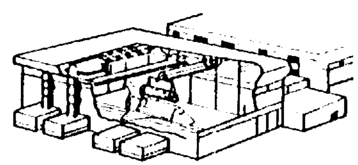

LAUNCH ASSEMBLY / TEST FACILITY

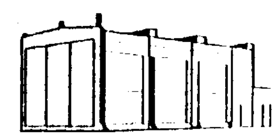

ORU & SPARES REFURBISHMENT / SUPPLY DEPOT


S^3 EQUIPMENT REFURBISHMENT / SUPPLY DEPOT (INTEGRATION)


S^3 MISSION CONTROL AND DATA PROCESSING


MANUFACTURING / TEST FACILITIES

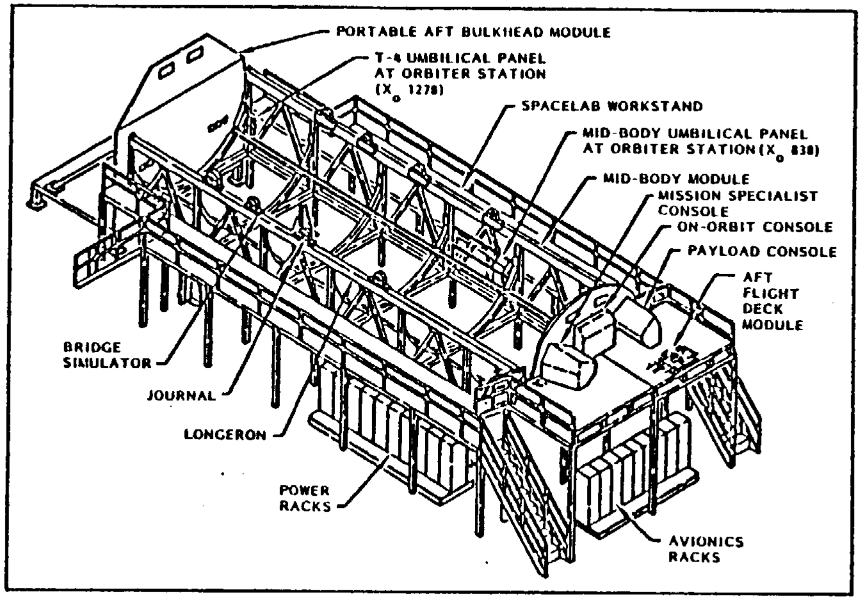

MOCKUP/SIMULATION AND TRAINING


EXPENDABLES SUPPLY DEPOT

LAUNCH SITE FACILITIES (TYPICAL)

Launch site facilities required for S^3 Operations (other than S^3 Depots) include both existing general-purpose facilities and additional dedicated areas. Two of these facilities are shown. The CITE shown is a general-purpose structural and functional check fixture. Some modifications are required to accommodate S^3 equipment.

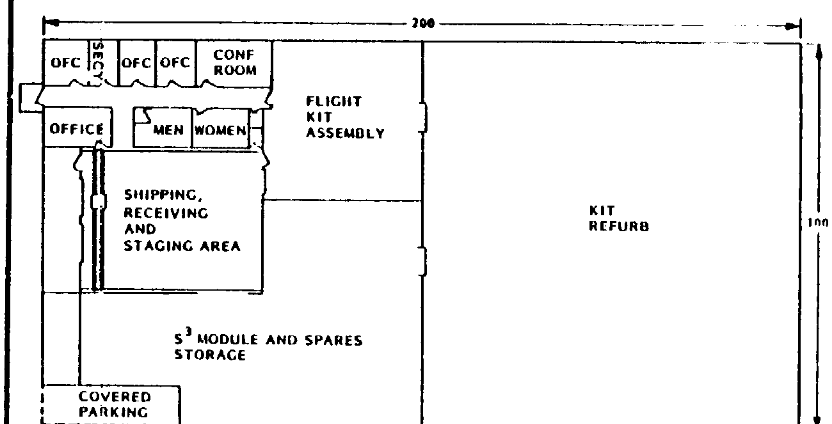
Launch Site Facilities (Typical)



CARGO INTEGRATION TEST EQUIPMENT (CITE)

- GFE FIXTURE AT LAUNCH SITE
- PRELAUNCH INSTALLATION OF S^3 EQUIPMENT AND OTHER CARGOS TO PROVE FITS AND ELECTRICAL/ MECHANICAL INTERFACES

- AREA DEDICATED TO ASSEMBLY AND CHECKOUT OF SERVICING EQUIPMENT MODULES FOR SPECIFIC SHUTTLE FLIGHTS
- STORAGE FOR MODULES TO SUPPORT SEVERAL PLANNED MISSIONS
- KIT REFURBISHMENT CAPABILITY



S^3 EQUIPMENT FLIGHT-READY AREA

PRODUCTION/TEST FACILITIES

Facilities exist today for manufacturing and testing of the planned S^3 equipment. They are not dedicated to the S^3 development and production programs. However, with proper planning and schedule integration, the contractors and Government combined facilities can accept the S^3 hardware/software work load.

Many of the S^3 equipment items are large (in the assembled configuration) and require fairly large floor areas and/or ceiling heights. Although large test facilities are not as numerous as the manufacturing; S^3 schedules can be accommodated if sufficient advanced planning and facilities interface coordination is done. A Facilities Working Group is planned as part of the S^3 central management team.

Production/Test Facilities

- EXISTING FACILITIES CAN SUPPORT THE PLANNED SATELLITE SERVICING SYSTEM
- LARGE FACILITIES ARE REQUIRED; THE LARGER S^3 COMPONENTS WILL TEND TO FILL THE ORBITER BAY – 15 FT DIAMETER
  - DEPLOYMENT PLATFORMS
  - STOWAGE CONTAINERS
  - RESUPPLY TANKAGE
- PRINCIPAL LARGE-FACILITY ITEM OR AREAS:

– THERMAL VACUUM CHAMBER	30 DIAM X 78 L (FT)
– ACOUSTIC CHAMBER	40 W X 50 L X 85 H (FT)
– STRUCTURAL TEST	40 W X 40 L X 50 H (FT)
– ASSEMBLY AND INTEGRATION	40 W X 100 L X 50 H (FT)
– CLEAN ROOM	

Implementation Plan

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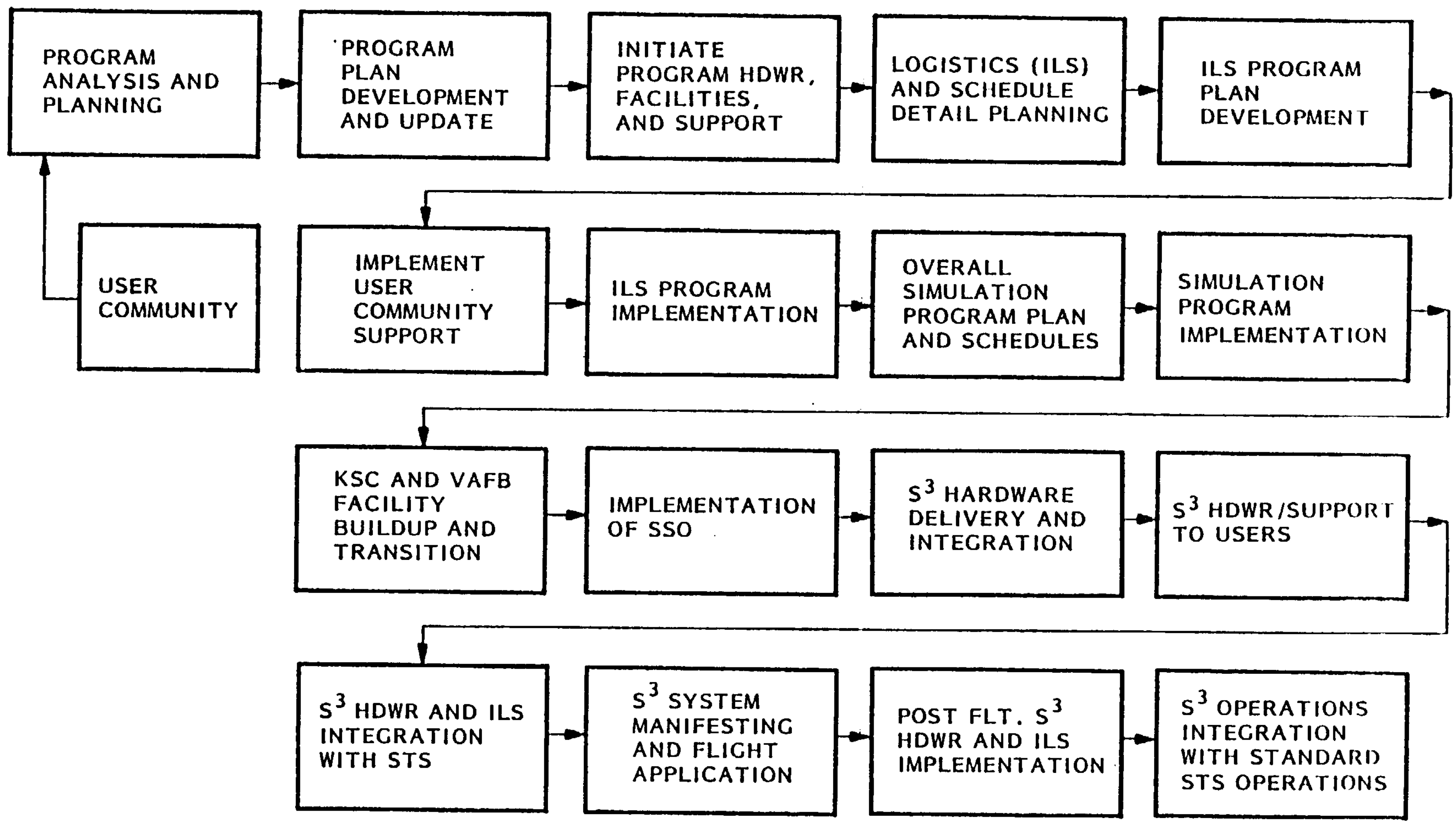
S^3 IMPLEMENTATION PLAN

The tasks required to establish and implement the Satellite Service Systems are shown in the sequential relationship. The plan presented here indicates the implementation elements required. The organization of efforts and the implementing organizations involved can be established by a variety of means.

S^3 Implementation Plan



PROGRAM SCHEDULE

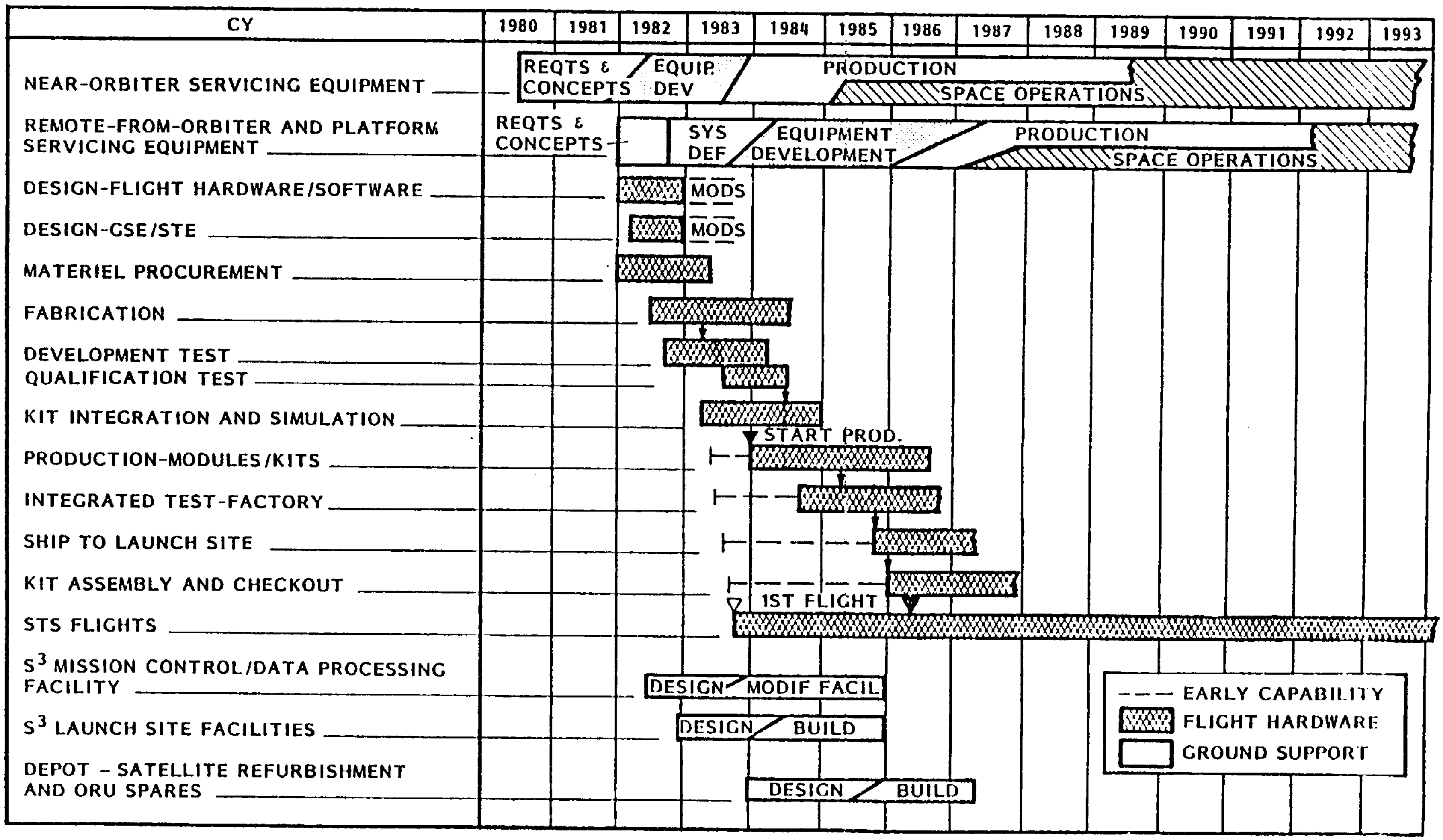
This master schedule for the S^3 Development and Production phase is divided into two parts showing separately the Near-Orbiter or early S^3 equipment schedule and the longer term HEO/GEO service hardware development schedule.

Compressing the schedule is feasible if a high-priority is assigned to the S^3 programs and prototype development and flight test approach is adopted. The flight dates for full complements of S^3 equipment are shown to be 1986 and late 1989 under normal development scheduling appear to lag the need dates for several of the planned NASA missions. The accelerated appraoch is shown in dashed lines.

The implementation of facility designs also is critical. To have the facility modification completed when needed for S^3 operations design should start no later than mid-1982.

S^3 Program Schedule

NASA LOCKHEED



SATELLITE SERVICING LOGISTIC PLAN

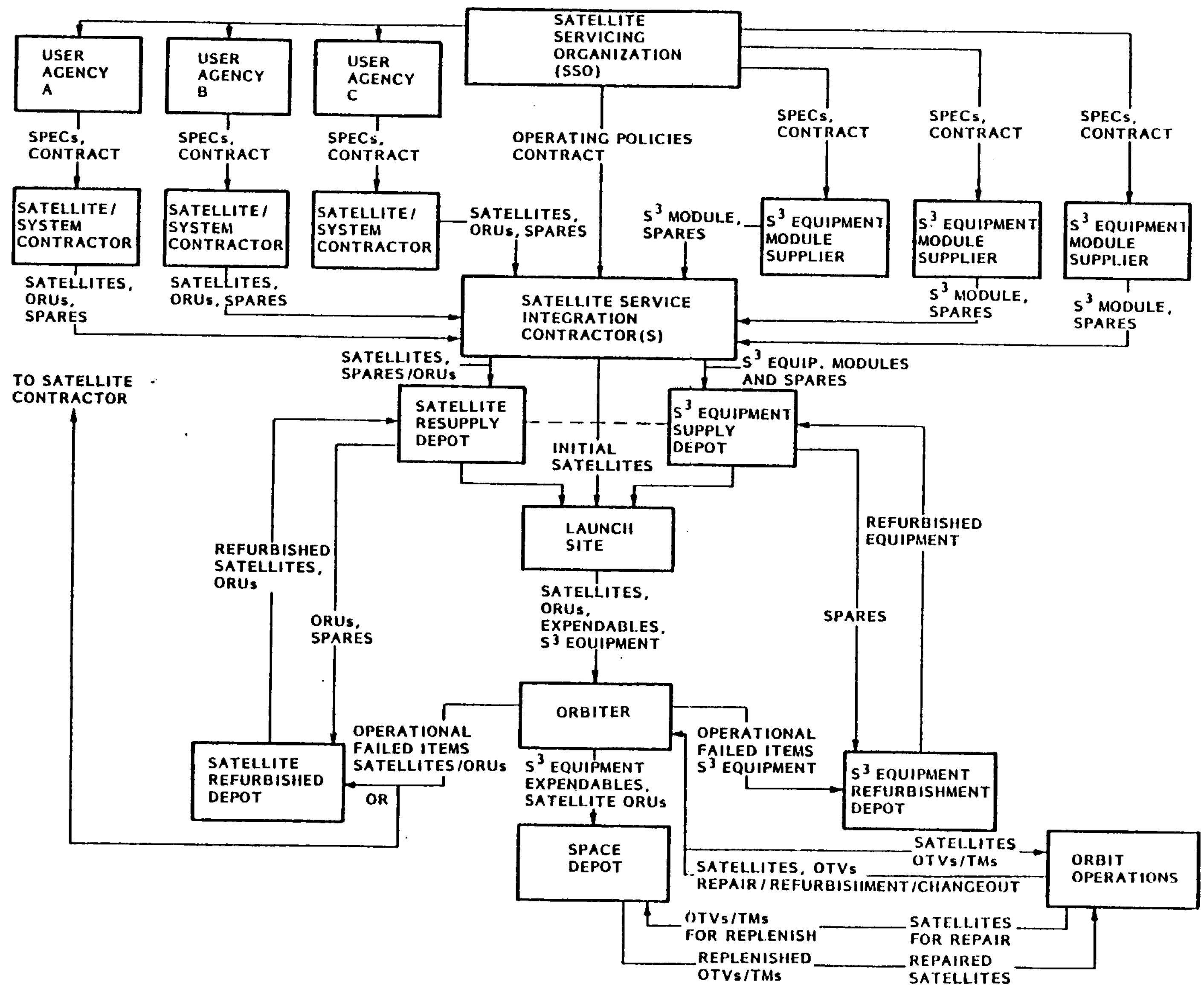
To implement the broad-scope S^3 program, a central Satellite Servicing Organization is highly desirable. It can direct procurement of S^3 equipment modules and direct the integration of this equipment with the User hardware.

Integration contractor(s) assist the central organization in implementing the logistic network.

The basic logistic flow of Satellites and S^3 equipment and the spares for each, through the orbit and ground operations cycles is shown. Repair/refurbishing and reuse of satellite modules and S^3 equipment is emphasized.

Satellite Servicing Logistic Plan

NASA — LOCKHEED



PROCUREMENT STRATEGY

The existence of a central organization for all space servicing provides several advantages. One is the consolidation of procurement for all material to support satellite service. Another is the standardization of documentation which reduces duplication of effort and uncertainty in definition of interfaces.

Procurement Strategy

- CENTRAL MANAGEMENT – ESTABLISH SINGLE ORGANIZATION IN SATELLITE SERVICING TO COORDINATE ALL SPACE LOGISTIC MATERIAL REQUIREMENTS AND PROCUREMENT
- PLANNED INVENTORY – CONSOLIDATE SATELLITE SERVICE MATERIAL INVENTORY CONTROL FOR ALL USERS (NASA, DOD, ET AL)
- INTEGRATED PROCUREMENT – BUY QUANTITIES TO SUPPORT ALL USER NEEDS

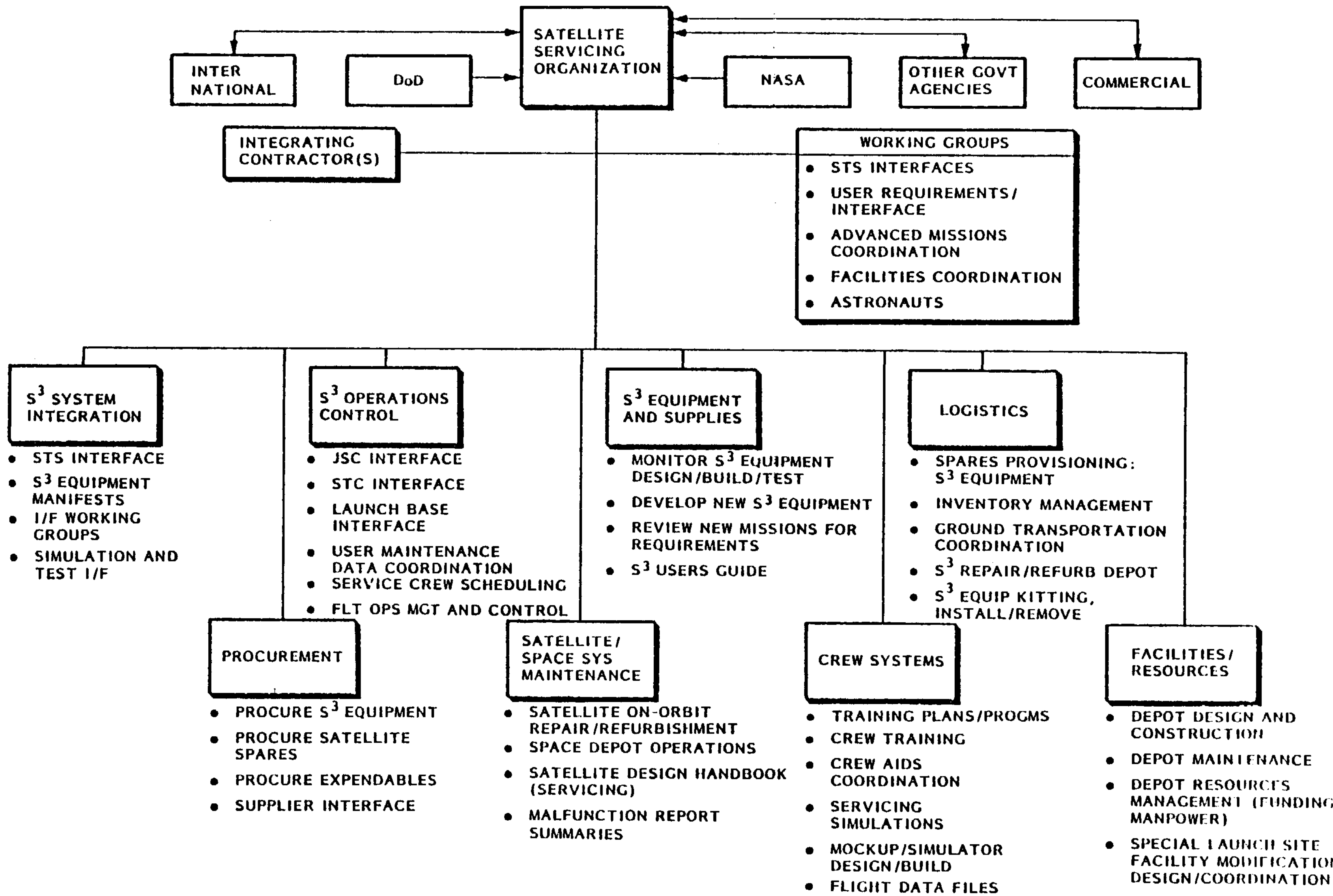
S^3 PROGRAM MANAGEMENT APPROACH

The implementation of an effective Satellite Services System requires effective, well coordinated management. A proposed organization is shown. It includes the central (JSC) Satellite Servicing Organization (SSO) and a directorate for each of the primary functions of the S^3 program.

In addition, working groups and integrating contractors are shown in staff positions to coordinate and maintain interfaces with critical user agencies and support elements.

S^3 Program Management

NASA LOCKHEED



GROUND SEGMENT MAINTENANCE OPERATIONS

The planned S^3 maintenance and Supply depots can refurbish orbit replaceable units and S^3 equipment. These depots may or may not be colocated.

The ORU Reburb Depot may process ORU's back to the supplier if production lines are still in tact. However, with the exception of the MMS spacecraft modules (ORU's) and a selected few other "series" of spacecraft equipment, production lines cannot be expected to remain open indefinitely. The S^3 ground segment is identified as the system element which maintains the continuity of equipment and skills required for an integrated long-duration servicing operation.

Ground Segment Maintenance Operation

IMPLEMENT TWO FUNCTIONAL GROUND DEPOTS:

S^3 EQUIPMENT REPAIR/REFURBISH/SUPPLY DEPOT

- REPAIR S^3 EQUIPMENT
- REFURBISH AND RETEST S^3 EQUIPMENT PERIODICALLY
- MAINTAIN SPARES IN READY STATUS

SATELLITE AND ORU REPAIR/REFURBISH/SUPPLY DEPOT

- REPAIR ORUs
  - COMMAND/DATA MANAGEMENT
  - GUIDANCE/CONTROL
  - ELECTRICAL POWER
- MAINTAIN SPARES READY STATUS

NASA

3.2 Satellite Services Development Plan

INTRODUCTION
ENGINEERING AND DEVELOPMENT REQUIREMENTS
STS REQUIREMENTS/INTERFACES
DEVELOPMENT TESTS AND SIMULATION
DDT&E SCHEDULE

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NASA

Introduction

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DEVELOPMENT PLAN OBJECTIVE

This Development Plan is one of three documents defining the implementation of the Satellite Services System. The Program Plan and Operations Plan complete the set.

Development Plan Objective

- DEFINE THE REQUIREMENTS FOR AND THE ACTIVITIES NECESSARY TO DESIGN, BUILD, AND TEST THE PROTOTYPE UNITS OF THE S^3 AND VERIFY READINESS FOR SPACE OPERATIONS WITH THE STS AND A WIDE VARIETY OF SATELLITES AND PLATFORMS IN THE 1983 TO 1993 TIME PERIOD.

  - THE DEVELOPMENT PLAN IS A MAJOR PORTION OF THE PROGRAM PLAN
  - THE DEVELOPMENT PHASE ENDS WITH THE SPACE-QUALIFICATION TESTING OF THE FIRST ARTICLES. THE S^3 PROGRAM CONTINUES WITH THE PRODUCTION AND SPACE OPERATION OF DUPLICATE SETS OF THE DEVELOPMENT HARDWARE.

SCOPE OF DEVELOPMENT PLAN

Because of the wide scope of the proposed Satellite Service System, the development is divided into three echelons or phases. These can be separately implemented if the funding is constrained. However, all S^3 planning should include all three echelons to ensure an eventual full-service capability.

Scope of Development Plan

DEVELOPMENT OF HARDWARE AND SOFTWARE TO COVER THREE PHASES OF SATELLITE SERVICE:

INITIAL: NEAR-ORBITER

- SERVICING OF SATELLITES AND SPACE VEHICLES IN LEO; DIRECTLY ACCESSIBLE BY ORBITER

EXPANDED: REMOTE OPERATIONS

- SERVICING OF SATELLITES REMOTE FROM ORBITER (HIGH-ALT, ELLIP. ORBIT, OR GEO)
- LARGER VEHICLES AND PLATFORMS IN LEO

SPACE BASED

- SERVICING OF SPACE VEHICLES, IN SAME LEO ORBIT INCLINATION AS MANNED SPACE STATIONS (SPACE OPERATIONS CENTER OR EQUIVALENT)
- SERVICING DONE ON SPACE DEPOT, UTILIZING TMS AND OTV

NASA

Engineering and Development Requirements

Lockheed

S^3 EQUIPMENT REQUIREMENTS

The S^3 requirements will be established in detail in the development phase. Several of the generally applicable equipment requirements are outlined in this chart.

The overriding requirement is to perform each unit of satellite service missions with equipment and methods resulting in the lowest life-cycle-costs for the total system including the satellite missions and the S^3.

S^3 Equipment Requirements

- DESIGN LIFE
  - (WITH PERIODIC REFURB) ---------- 15 YEARS
- STORAGE
  - LONG-DURATION DORMANT ---------- 5 YEARS
  - GROUND OR SPACE ENVIRONMENT
- REPAIRABLE
  - MODULAR CONSTRUCTION
  - REPAIRABLE ON-ORBIT AND GROUND
- OPERATION BY ON-ORBIT CREWPERSON
  - REMOTE CONTROL VIA DISPLAY/CONTROL PANEL
  - PARALLEL MECHANISM FOR MANUAL OPERATION
  - EVA BACKUP FOR AUTOMATED EQUIPMENT (MOTORS, ETC)
- VERSATILITY
  - USABLE WITH ORBITER OR SPACE DEPOT AS OPERATING BASE
- SAFETY
  - MAN-SAFE RATING

TYPICAL DEVELOPMENT HARDWARE

A number of the required smaller elements of S^3 equipment required are either being produced in support of NASA programs, e.g., the Space Telescope program, or are in various stages of design or development. Most of this hardware is in the "crew aids" category and supports the servicing operations conducted by EVA.

The princial hardware elements requiring development or completion of development are listed on this and the following two charts. This equipment requires early development so that the S^3 capabilities keep pace with the planned increase of the space vehicle traffic.

Development of the listed items is included in S^3 implementation plans.

Typical Development Hardware (1 of 3)

- DEPLOYMENT AND MAINTENANCE PLATFORM – PROVIDES SECURE ATTACHMENT OF A SATELLITE IN THE ORBITER BAY AND THE NECESSARY DEGREES OF ROTATIONAL FREEDOM FOR PERFORMING SERVICE FUNCTIONS OF DEPLOYMENT, CHANGEOUT, RE-CONFIGURATION, RESUPPLY, REPAIR, OR STOWAGE FOR EARTH RETURN.
- BULK CARGO STOWAGE OR TIEDOWN – RESTRAINS IRREGULAR HARDWARE ELEMENTS IN ORBITER CARGO BAY FOR RETURN TO EARTH. ACCOMMODATES SATELLITES AND OTHER SPACE EQUIPMENT WHICH ARE DAMAGED OR DO NOT HAVE PROVISIONS FOR NORMAL ORBITER SILL OR KEEL MOUNTS.
- MODULE EXCHANGE KIT – REMOTE AUTOMATED – USED IN CONJUNCTION WITH TMS OR OTV FOR REPAIRING SATELLITE IN SITU (WITHOUT RETURNING TO ORBITER OR SPACE DEPOT). USED IN INITIAL REPAIRS TO SATELLITES IN GEO: OTV CARRIES REPLACEMENT ORUs TO GEO, DOCKS AND EXCHANGES ORUs, AND RETURNS TO DOCK WITH ORBITER OR SPACE DEPOT IN LEO. USED IN CONJUNCTION WITH TELEOPERATOR MODULE.
- SATELLITE CHECKOUT SET – MODULE FAILURE DISCRIMINATION AND TEST OF PRIMARY SUBSYSTEM FUNCTIONS. CHECKOUT VIA HARDLINE UMBILICAL TO SATELLITE. ALSO, WITH ADAPTIVE SOFTWARE, CHECKOUT OF MTV, OTV, AND TMS.

Typical Development Hardware (2 of 3)

- FLUID TRANSFER MODULE – TRANSFER OF FLUIDS FROM TANKAGE IN ORBITER CARGO BAY TO SATELLITE, OTV, TMS. FLUIDS INCLUDE HYDRAZINE, LH_2, LO_2, NITROGEN. HIGH FLOW RATE TO ALLOW TRANSFER UP TO 15000 LB/HR. ANCILLARY MODULES TO TRANSFER CRYOGENS TO SATELLITE DEWARS.

- TELEOPERATOR MANEUVERING SYSTEM
  - TELEOPERATOR FUNCTION – MECHANISM FOR DOCKING WITH FREE-FLYING SATELLITE AND PERFORMING BASIC MECHANICAL FUNCTIONS: OBSERVATION, OPEN DOORS, EXCHANGE SMALLER ORUs, ACTIVATE/DEACTIVATE, OR DISASSEMBLE/JETTISON APPENDAGES. MOUNTS ON MANEUVERING STAGE.
  - MANEUVERING FUNCTION – TRANSFER SATELLITES OR OTHER CARGO BETWEEN FREE-FLYER ORBIT AND ORBITER OR BETWEEN SPACE DEPOT AND FREE-FLYER ORBIT. CARRY LARGE PROPELLANT LOADS, UP TO 8000 LB. FLY ON PRE-PROGRAMMED TRAJECTORY WITH AUTOMATED RENDEZVOUS/DOCKING WITH SATELLITE. FLOWN BY REMOTE CONTROL FROM ORBITER (OR GROUND) WITH TV FEEDBACK.

- ORBITER BERTHING/DOCKING MODULES – PROVIDES FOR RENDEZVOUS AND DOCKING OF ORBITER TO LARGE SPACE VEHICLES AND PLATFORMS: E.G., 25kW POWER SYSTEM, SCIENCE/APPLICATION PLATFORMS, SOC, ETC. MOUNTS IN ORBITER FWD CARGO BAY. USES RANGE/RANGE-RATE, ANGULAR, AND DOCKING-AXIS ALIGNMENT SENSORS INPUTTING TO ORBITER VERNIER RCS FOR AUTOMATED DOCKING (MANUAL OVERRIDE WITH TV LOOP). AUTOMATED ELECTRICAL UMBILICAL CONNECT/DISCONNECT WITH MANUAL BACKUP.

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Typical Development Hardware (3 of 3)

- RENDEZVOUS/DOCKING – REMOTE CONTROL – PROVIDES CONTROL FROM ORBITER OR SPACE DEPOT FOR REMOTE RENDEZVOUS AND DOCKING; OTV OR TMS TO SATELLITE, SPACE PLATFORM, ORBITER. INCLUDES VISUAL DISPLAYS AND SENSING/PROPULSION ELECTRONICS.

- MANNED TUG – PRESSURIZED COMPARTMENT WITH INTEGRAL PROPULSION AND TRANSLATION/ATTITUDE CONTROL. DOCKING MECHANISM AND TELEOPERATOR ARMS CONTROLLED FROM WITHIN. USED FOR CREW MOBILITY IN INSPECTION, MINOR SERVICING, APPENDAGE REMOVAL, AND TRANSFER OF SATELLITE IN GENERAL VICINITY OF ORBITER OR SPACE DEPOT.

NASA

STS Requirements and Interfaces

Lockheed

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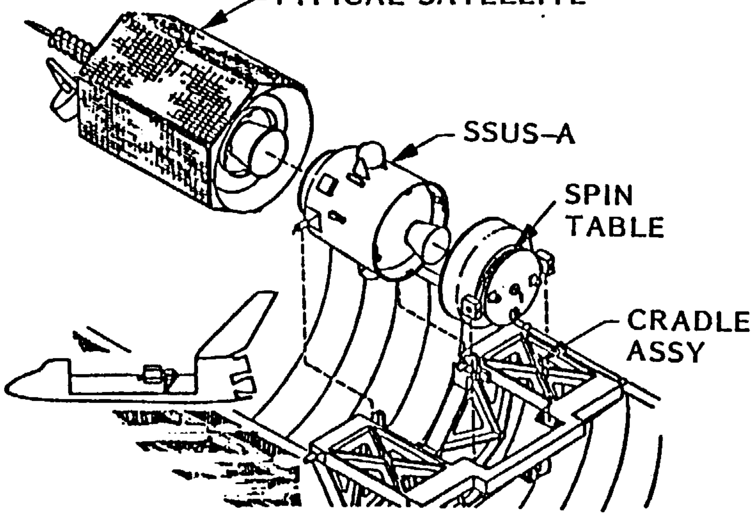
SPACE TRANSPORTATION SYSTEM

The principal elements of the STS are illustrated; they supplement and support the S^3 operations.

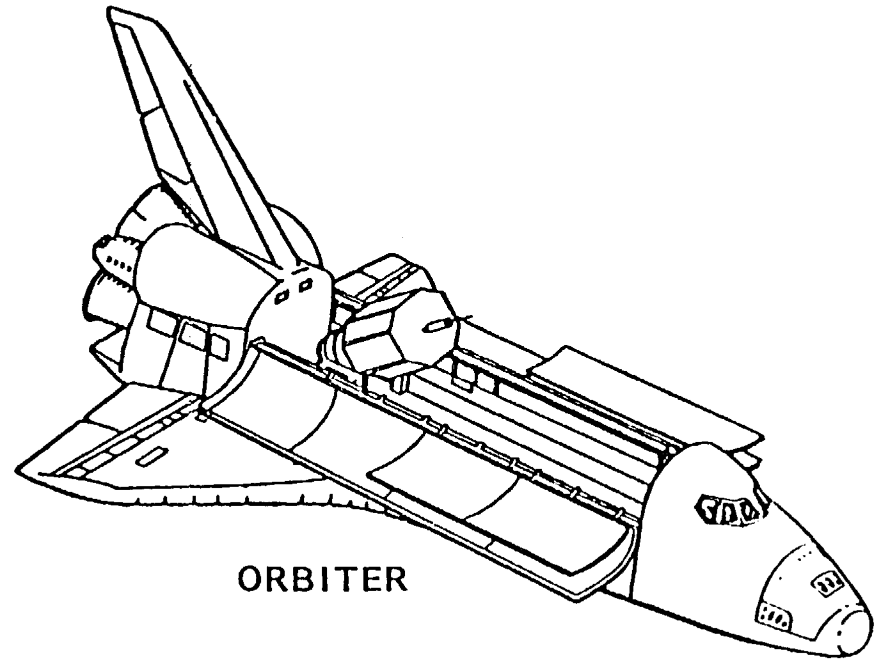
The Spin Stabilized Upper Stage (SSUS) is utilized to deliver spinning satellites to their terminal orbit positions.

The wide-body Centaur is a newly added STS inventory item. It provides boost for space probes and HEO/GEO satellies. A low-thrust-level boost stage can accomplish a round-trip to perform placement or revisit servicing mission to GEO and return to LEO. It would be based in LEO on a permanent platform, the SOC, or the planned S^3 space depot. Replenishment propellant is supplied duirng revisits to the space platform.

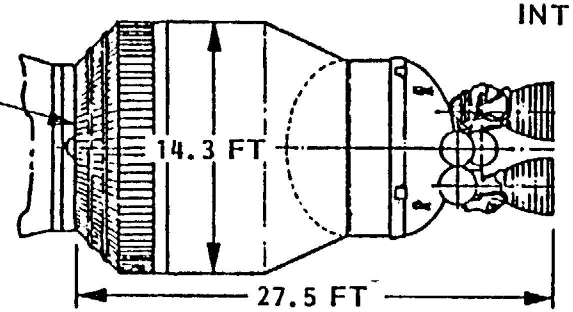
The SSUS, Centaur, and IUS, mounted in the Orbiter will be supported by S^3 equipment.



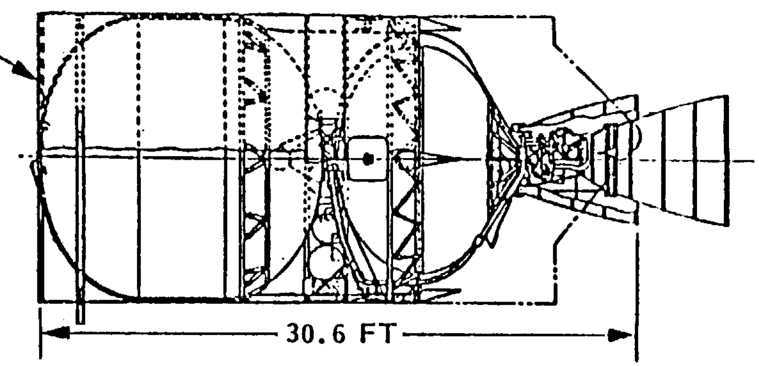
SSUS OTV



ORBITER



CENTAUR OTV



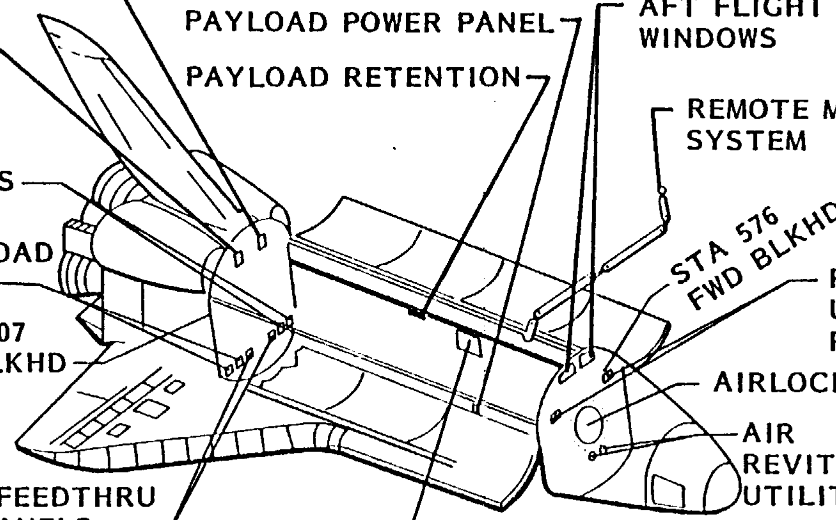
IUS OTV

PRINCIPAL STS/S^3 INTERFACES

Development of the S^3 equipment emphasizes the need for interface mating with the existing standard Orbiter equipment and operations. Mechanical and functional testing; simulation and training is part of the S^3 development program.

A primary operations interface involves the free-flight control of the MTV and TMS vehicles and the positioning and translation of the Orbiter. Dynamic simulation of all operations including approach and docking of the free flyers are included in the plans.

Principal STS/S^3 Interfaces (1 of 2)



- S^3 INTERFACES WITH THE STS ARE ESTABLISHED EARLY, MAINTAINED ON ICDs, AND REVIEWED/UPDATED BY FREQUENT MEETINGS OF AN STS INTERFACE WORKING GROUP

- THE ORBITER INTERFACE COORDINATION WILL BE EXTENDED TO OTVs AS LATTER ARE USED FOR REUSABLE PROPULSION STAGES

Principal STS/S^3 Interfaces (2 of 2)

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ORBITER INTERFACES:

- FLIGHT CONTROL
  - I/Fs AMONG ORBITER VERNIER AND MAIN RCS CONTROLS, RMS CONTROLS, SATELLITE/TMS/MTV FOR RETRIEVAL, DOCKING, AND DEPLOYMENT
- STRUCTURAL
  - MOUNTING AND LOAD TRANSFER FOR S^3 RACKS/PLATFORMS
- ELECTRICAL
  - I/F WITH ORBITER POWER SUPPLY: VOLTAGE AND FREQUENCY
- DATA PROCESSING
  - I/F WITH ORBITER ONBOARD COMPUTERS AND DATA MANAGEMENT SYSTEM
- COMMUNICATION
  - I/F VIA ORBITER WITH TDRS, STDN, AND DoD SGLS COMMUNICATION SYSTEMS
- FLUID SYSTEMS
  - SPECIAL VENT AND ABORT DUMP I/Fs FOR S^3 REPLENISHMENT FLUIDS

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ORBITER ACCOMMODATIONS FOR S^3

The orbiter capability is supplemented by special S^3 Orbiter Accommodation equipment. The general requirements for Orbiter interfaces are covered in Vol. XIV, JSC 07700 Space Shuttle System Payload Accommodations.

The design of equipment necessary to interface the S^3 hardware to the orbiter is a part of the S^3 Development Program.

Mission-unique designs are avoided; multi-dimension application of common equipment is stressed.

The exact definition of what constitutes "Satellite Service" Equipment and what equipment is ancillary to normal user programs requires decision on a case by case basis. The interface items listed in this and the following chart are on this poorly defined border line.

Orbiter Accommodations for S^3 (1 of 2)

THE S^3 ORBITER ACCOMMODATION EQUIPMENT SUPPLEMENTS THE ORBITER CAPABILITY

ORBITER CAPABILITY	S^3 ACCOMMODATION EQUIPMENT
• STRUCTURAL MOUNTING POINTS – CARGO BAY	• LONGERON BRIDGE FITTINGS
• PAYLOAD OPERATOR STATION	• MISSION-UNIQUE DISPLAY/CONTROL PANELS – SATELLITE CHECKOUT PANEL – TMS/MTV REMOTE OPS CONTROL PANEL – SATELLITE RETRIEVAL/DOCK/DEPLOY CONTROL PANEL
• COMPUTER/DATA PROCESSING	• SOFTWARE • SATELLITE CHECKOUT SET
• RMS	• SPECIAL PURPOSE RMS • SPECIAL END EFFECTORS

Orbiter Accommodations for S^3 (2 of 2)

ORBITER CAPABILITY	S^3 ACCOMMODATION EQUIPMENT
• COMMUNICATION LINKS (RF, VOICE)	• S^3 I/F UNIT • SPECIAL S^3 DATA MULTIPLEXING AND DATA COMPRESSION PACKAGE
• BASIC ILLUMINATION AND TV	• ANCILLARY LIGHTS (PORTABLE) AND TV CAMERAS
• CREW SUPPORT EQUIPMENT FOR TWO CREW MEMBERS	• ADDITIONAL CREW EQUIPMENT AND LIFE SUPPORT SUPPLIES FOR ADDED EVA s

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Development Tests and Simulation

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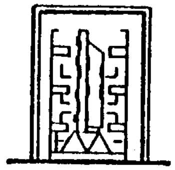
DEVELOPMENT TESTS

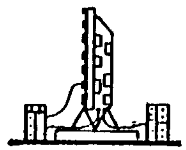
In the broad sense, development phase testing incudes both the development testing of prototype hardware and the qualification testing of First-Article flight items.

The tests separately done by each S^3 equipment supplier on an equipment-by-equipment basis. An integrating contractor is needed to accomplish the integrated-system testing.

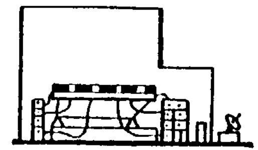
Development Tests



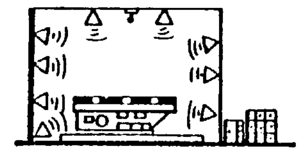
MECHANICAL VERIFICATION



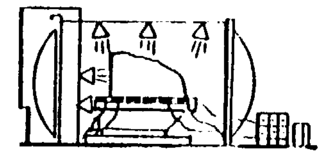
INTEGRATED FUNCTIONAL TEST WITH SAT SIMULATOR



ELECTROMAG. COMPATIBILITY (EMC)



ACOUSTIC ENVIRONMENT



THERMAL–VAC ENVIRONMENT

TESTS	TEST EQUIPMENT
COMPONENT/MODULE TESTS • STRUCTURAL LOAD/DYNAMIC • OUTGASSING • EMC • ACOUSTIC • THERMAL VACUUM • MECHANICAL FUNCTION	• MECHANICAL LOADING FIXTURES • DYNAMIC TEST FIXTURE • ENVIR. TEST FIXTURES • ACOUSTIC TEST CHAMBER • THERMAL/VAC TEST CHAMBER • POWER SUPPLY • TEST CONSOLES AND SOFTWARE
INTEGRATED SYSTEM FUNCTION • UMBILICAL MATE/DEMATE • SATELLITE CHECKOUT • SOFTWARE PROOFING	• SATELLITE FUNCTIONAL SIMULATOR • S^3 CHECKOUT SET (BREADBOARD) • S^3 DISPLAY/CONTROL PANELS (BREADBOARD) • PROTOTYPE S^3 SOFTWARE (GROUND AND FLIGHT) • POWER SUPPLY

SIMULATION TESTING

Ground simulation of the servicing operation is vital to the development of the S^3 equipment designs, the design of operational timelines, and the constraints placed on the user satellite design.

Early phase satellite servicing involves a large measure of man-in-the loop execution. The simulation program verifies the equipment and operations design for ease and safety of the crew.

Later phases using remote and automated operations require even more extensive simulation to verify the "robotics" capabilities in all permutations of conditions that could be encountered in performing the service.

Simulation Testing (1 of 2)

SIMULATION	PROTOTYPE S^3 EQUIP AND SIMULATORS
• MODULE (ORU) REPLACEMENT – EVA – SATELLITE ON RMS – SATELLITE ATTACHED TO DMP – (NEUTRAL-BUOYANCY, 6 DOF, OR 1G)	• STD RMS AND END EFFECTORS (GFE) • SPECIAL RMS (2ND) • DEPLOYMENT AND MAINTENANCE PLATFORM • SATELLITE SIMULATOR • ORU SIMULATORS
• MODULE (ORU) REPLACEMENT – AUTOMATED – MODULE EXCHANGE MECH – RMS TRANSFER – (1G AIR-BEARING FLOOR)	• MODULE EXCHANGE MECHANISM • SATELLITE SIMULATOR • ORU SIMULATORS • RMS AND END EFFECTORS • S^3 DISPLAY/CONTROL PANELS
• MODULE REPLACEMENT – REMOTE FROM SHUTTLE – TMS OR OTV – (1G AIR-BEARING FLOOR)	• SATELLITE GRAPPLING/DOCKING MODULE • MODULE EXCHANGE DEVICE • SATELLITE SIMULATOR • ORU SIMULATORS
• RETRIEVE/DOCK SATELLITE/PLATFORM TO ORBITER – (1G AIR-BEARING FLOOR)	• BERTHING/DOCKING MODULE (PROTOTYPE) • DISPLAY/CONTROL PANELS – S^3 • LARGE PLATFORM OR SATELLITE SIMULATOR (PARTIAL) • VISUAL DOCKING AIDS • SENSING/CONTROL LOOP – DOCKING (BREADBOARD)

Simulation Testing (2 of 2)

SIMULATION

- LIGHTING AND TV
  - APPLY LIGHTING VARIATIONS TO ALL SIMULATIONS
    - EVA OPERATIONS
    - REMOTE OPERATIONS (TMS OR OTV)
- FREE-FLYER RETRIEVAL BY RMS
  - (1G AIR-BEARING FLOOR)
    - SATELLITE STABILIZED
    - SATELLITE SLOW TUMBLE

PROTOTYPE S^3 EQUIP AND SIMULATORS

- ILLUMINATION LIGHTS – FIXED AND PORTABLE
- TV CAMERAS
- SPACE ILLUMINATION SIMULATION FACILITY

- RMS AND END EFFECTORS
- SATELLITE SIMULATOR
- DEPLOYMENT AND MAINTENANCE PLATFORM

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DEVELOPMENT FACILITIES

Analyses and definition of satellite service equipment indicate that existing aerospace community facilities can support the S^3 development. Modifications are necessary to adapt some manufacturing and test facilites to S^3 funcitons.

A primary early development phase activity plans the facilities in detail and initiates design of modifications, floor layouts, utilities, etc.

Early commitment of facility floor space and reservation of special test facilities for S^3 operations is necessary.

Development Facilities

- EXISTING FACILITIES CAN SUPPORT THE PLANNED SATELLITE SERVICE SYSTEM DEVELOPMENT
- LARGE-SIZE FACILITIES ARE REQUIRED; THE LARGER S^3 COMPONENTS WILL TEND TO FILL THE ORBITER BAY – 15 FT DIA
  - DEPLOYMENT PLATFORMS
  - STOWAGE RACKS
  - RESUPPLY TANKAGE
  - TMS
  - MODULE EXCHANGE MECHANISM
  - DOCKING MODULE
- PRINCIPAL LARGE-FACILITY ITEM OR AREAS:

– THERMAL VACUUM CHAMBER	30 DIA X 78 L (FT)
– ACOUSTIC CHAMBER	44 W x 50 L x 85 H (FT)
– STRUCTURAL TEST	40 W x 40 L x 50 H (FT)
– ASSEMBLY, INTEGRATED TEST, AND SIMULATIONS	40 W x 100 L x 50 H (FT)
– MULTIPLE DOCKING FACILITY (MDF)	
– NEUTRAL BUOYANCY/WATER IMMERSION FACILITY	

DDT&E Schedule

S^3 EQUIPMENT DEVELOPMENT SCHEDULE

The schedule shown in this chart depicts two phases of satellite services equipment development. In each phase, examples of the more ambitious equipments are shown. The first phase indicates the development of the equipment necessary to initiate and maintain the service system within the scope of this study, i.e., orbiter based and near-orbiter service. The second phase shows the potential growth of the service system required to undertake remote service, large platforms, and spacebased service operations.

All hardware elements are presumed to go through prototype design and development test phases. Some equipment can be produced and flight tested in a "skunk works" program without full documentation and qualification. Such elements can shortcut the normal development schedule.

In general the development phase is considered ended with the completion of qualification. Some qualification units are refurbished and used as the first operational service quipment.

Production of all equipments needed to satisfy the service system over a 10 year span is shown to be accomplished in the most cost effective sequence even though ultimate quantity needs are years later. This approach minimizes the program cost.

S^3 Equipment Development Schedule (1 of 2)

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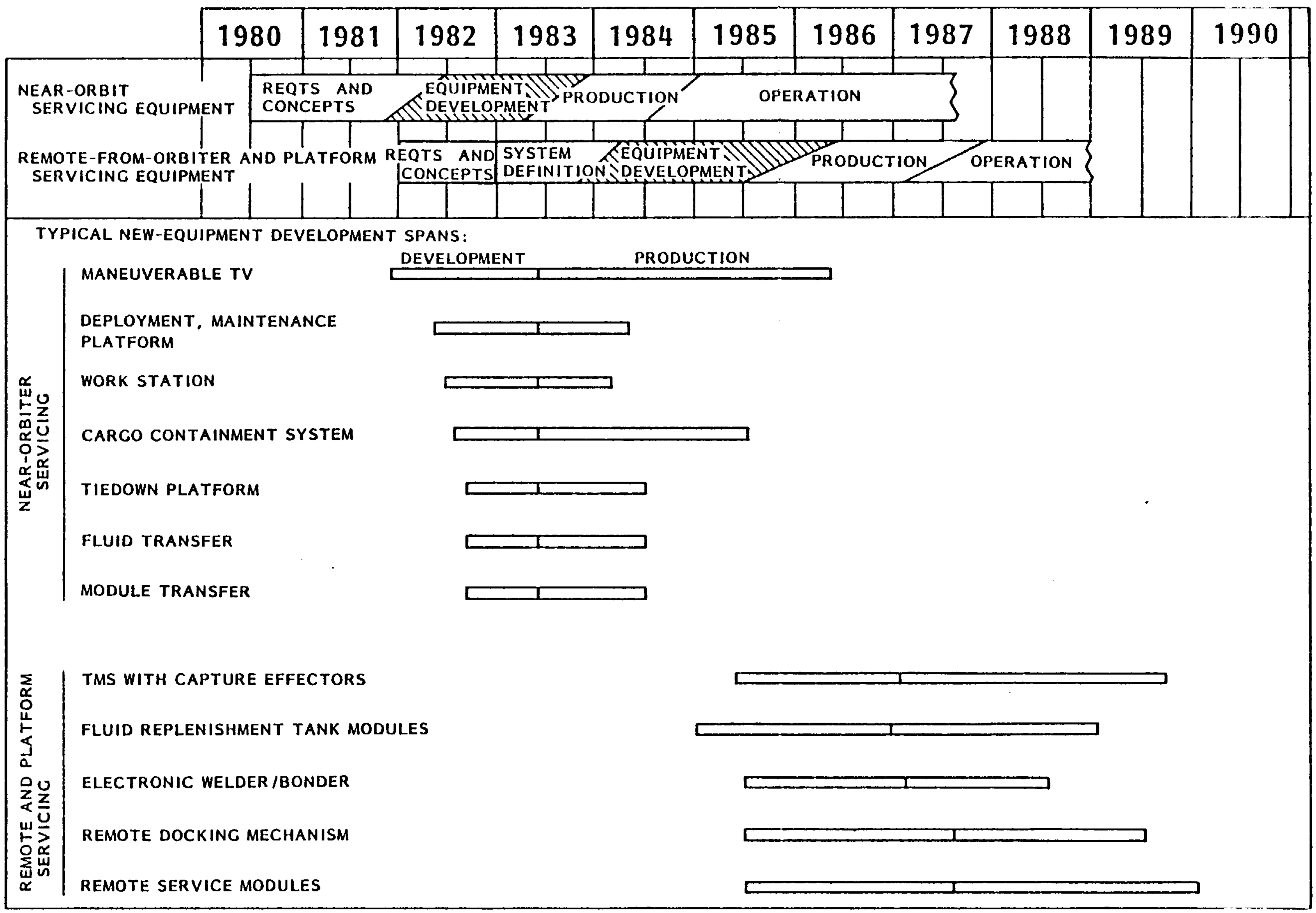

S^3 Equipment Development Schedule (2 of 2)

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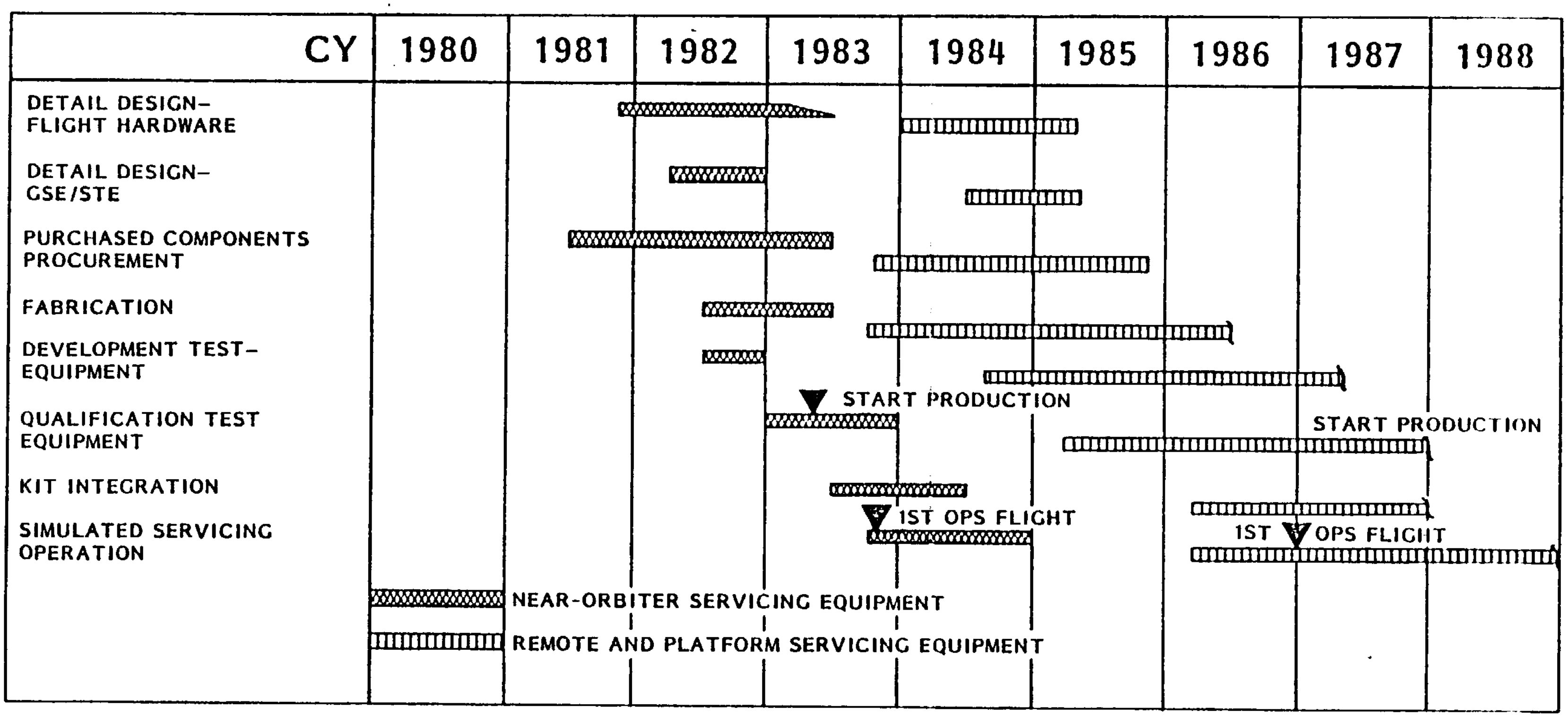

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3.3 Satellite Services Operations Plan

INTRODUCTION

REQUIREMENTS

TYPICAL S^3 LAUNCH AND FLIGHT OPERATIONS

TYPICAL S^3 GROUND SUPPORT OPERATIONS

S^3 OPERATIONAL PLANNING DOCUMENTATION

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Introduction

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OBJECTIVES OF THE S^3 OPERATIONS PLANS

The mission operations plans are identified as falling into one of several categories:

- Flight Support Operations for each of 6 Generic Missions
- Ground Support Operations
- Specific mission operations

The approach to this plan is to identify the elements required for the first and second categories. These generalizations indicate a lack of definition of the Satellite Service System organization responsibilities. The resolution of this probelm was to outline the plans for identificaion of the ultimate plan content. The specific mission operations plan is to be built on the generic plans in the preflight planning era.

Objective Of S^3 Operations Plans

DEFINE THE REQUIREMENTS FOR AND THE ACTIVITIES NECESSARY TO PROVIDE SERVICING OF OPERATIONAL SPACE SYSTEMS, BOTH IN ORBIT AND ON THE GROUND. THE STS AND THE SATELLITE SERVICES SYSTEM (S^3) ARE COMBINED TO SUPPORT DEPLOYMENT, OBSERVATION, RETRIEVAL, REPAIR, RESUPPLY, CHANGEOUT, RECONFIGURATION, AND EARTH RETURN.

- SATELLITES
- UPPER STAGES
- OTVs AND TMS
- SPACE PLATFORMS
- PLANETARY VEHICLES

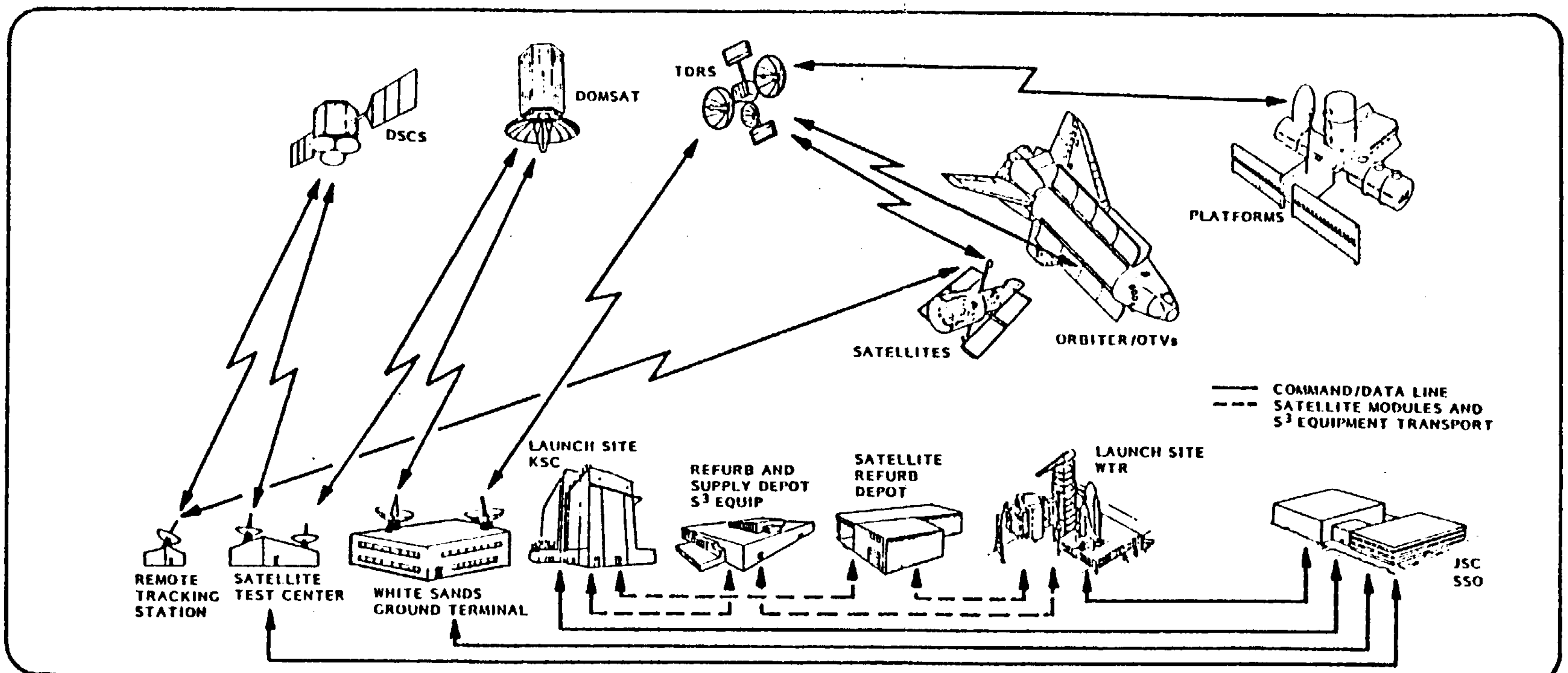
SCOPE OF THE OPERATION S^3

The operational S^3 supports the total earth-orbiting inventory of space vehicles and the checkout/deployment phase of STS launched satellites and planetary mission vehicles.

A multi-agency approach is planned combining the servicing requirements for NASA, DoD, other U. S. Government agencies, and eventually the commercial and international agencies (ESA, Japan, and others).

Scope of the Operational S^3

- SERVICING IS PROVIDED FOR A VARIETY OF SATELLITES, SPACE PLATFORMS (E.G., SOC), OTVs, AND OTHER SPACE SYSTEMS
  - EARLY PHASE (CIRCA 1983) SERVICING INCLUDES:
    - SATELLITE DEPLOYMENT AND RECOVERY
    - ORBITAL UNSCHEDULED EVA OVERRIDE OF APPENDAGES
    - LIMITED CHANGEOUT OF 'MODULES' AND BLACK BOXES
  - LATER PHASES EXTEND SERVICE TO MORE EXTENSIVE CHANGEOUT, RESUPPLY, DEBRIS CAPTURE/RETRIEVAL, REPAIR AND DEORBIT
- ALL STS USERS AND SOME EXPENDABLE LAUNCH VEHICLE USERS ARE POTENTIAL CUSTOMERS FOR S^3: NASA, USAF, DARPA, NAVY, COMMERCIAL, INTERNATIONAL



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Requirements

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S^3 MISSION OPERATION REQUIREMENTS

The basic elements making up the S^3 Operations are listed, and defined in this figure.

Specific responsibilities for management of each basic area are assigned within the Space Servicing Organization. Detail operations plans for each area will be constructed in accordance with the details which follow.

S^3 Mission Operation Requirements

PRELAUNCH OPERATIONS

- VERIFY S^3 EQUIPMENT PERFORMANCE AND SATELLITE/S^3 INTERFACES
- VERIFY S^3 EQUIPMENT FIT AND FUNCTIONAL INTERFACES WITH ORBITER

ORBIT OPERATIONS

- PERFORM SERVICE FUNCTION ON ASSIGNED SPACE VEHICLE

GROUND CONTROL CENTER OPERATIONS

- CONTROL OF FLIGHT SEGMENT SERVICE
- PERFORMANCE ANALYSIS OF SERVICE

NETWORK COMMUNICATIONS

- INTERFACE WITH NETWORKS: TDRS, STDN, USAF-SGLS (SECURE)

SERVICE CREW TRAINING AND SIMULATION

- PREPARE CREW FOR SPACE SERVICING OPERATIONS
- PROVEOUT AND REHEARSE – S^3 SERVICE METHODS AND EQUIPMENT FUNCTIONS

GROUND REPAIR/REFURB

- REPAIR/REFURB OF RETURNED S^3 EQUIPMENT
- REFURB RETURNED SATELLITE ORBIT REPLACEABLE UNITS (ORU)

LOGISTIC SUPPLY

- DEPOT SUPPLY OF: S^3 EQUIPMENT KITS AND SPARE PARTS, EXPENDABLES FOR RESUPPLY, AND ORUs

SPACE SEGMENT S^3 OPERATIONS ELEMENTS

The diagram shows the various elements of the S^3 space segment and their interfaces. The servicing base is shown to be either the Orbiter or the Space Depot (SOC).

S^3 Space Segment Operations Elements

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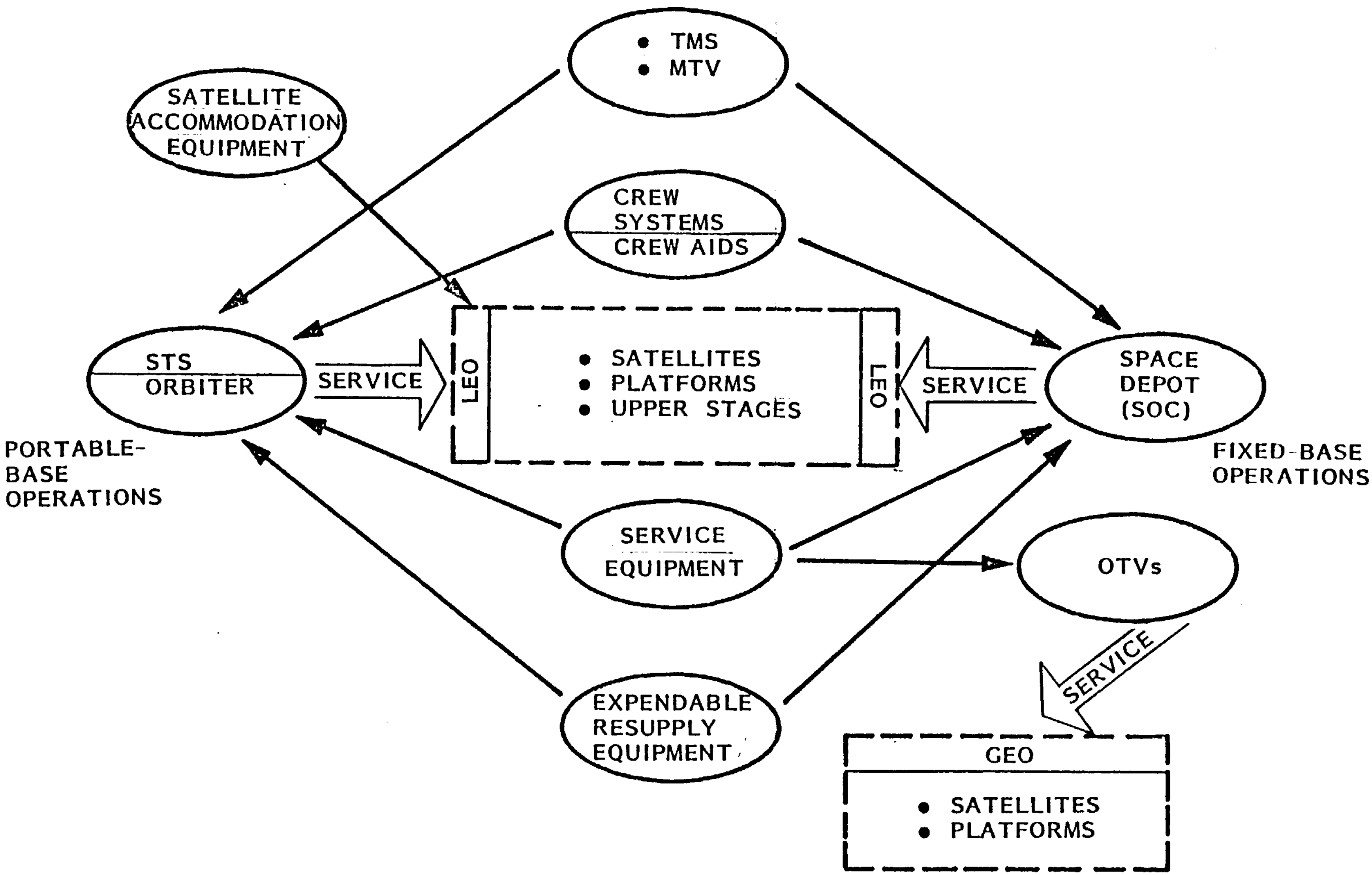
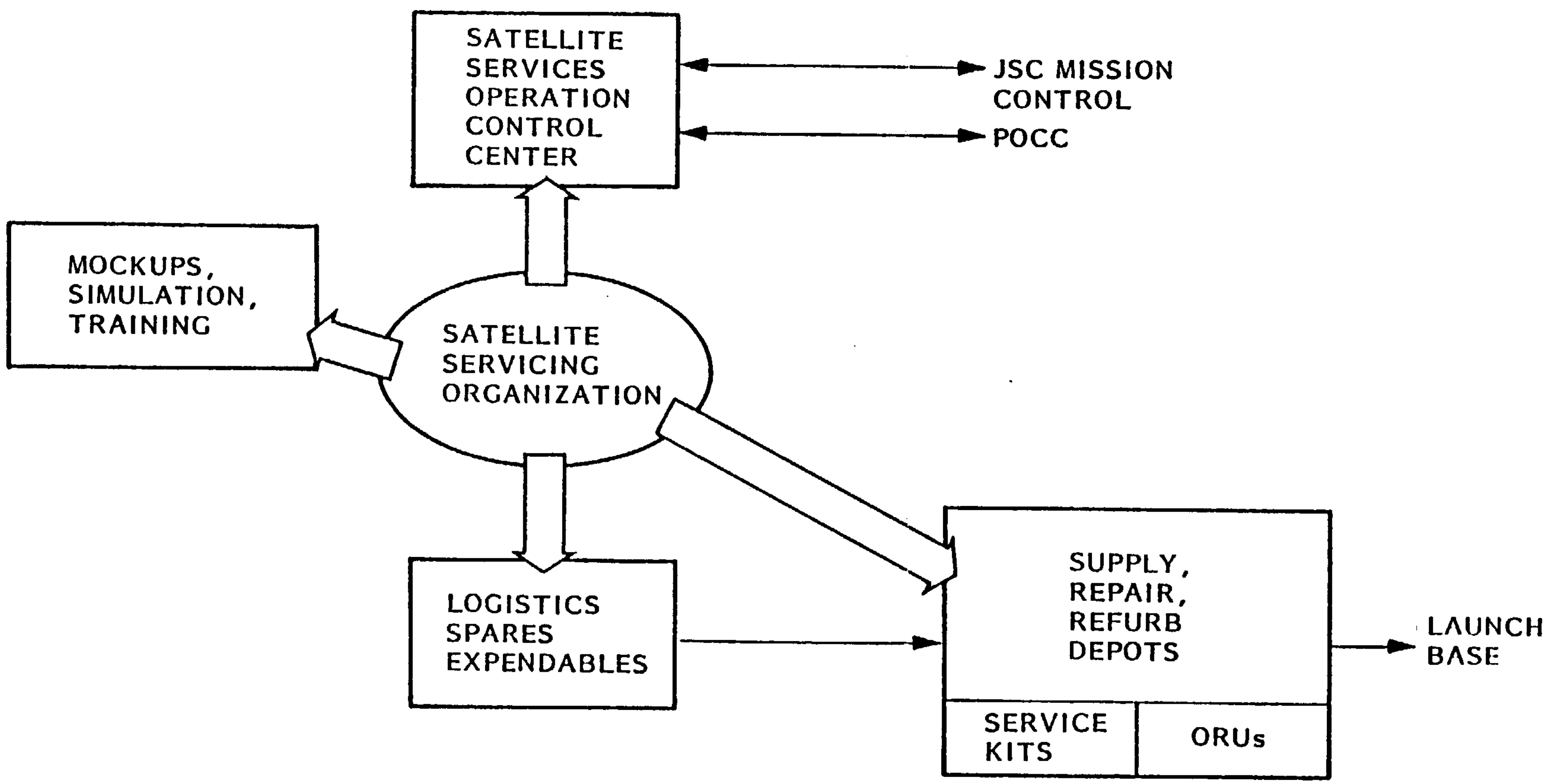


S^3 GROUND SEGMENT OPERATIONS ELEMENTS

The elements of the S^3 Ground Segment are shown in this figure. Examples of the interfaces with the primary operations organizations are indicated.

S^3 Ground Segment Operations Elements



S^3 MISSION SUPPORT MODEL

An analysis of planned missions for period 1983 to 1993 shows the distribution among the general service missions.

Multiple deployment missions can be accomplished on the same flight that performs one or more rendezvous/retrieve missions. The service missions are presumed to be "shared" missions for the purpose of cost estimating. In this way, the cost allocated to a servicing mission can be kept relatively low. Dedicated service missions could be planned but it will be significantly more costly.

Sortie missions might be shared with HEO/LEO/Planetary Spacecraft deployments but not likely with the other types because the limited endurance of the orbiter will likely be fully dedicated to the purposes of the Sortie payload.

The ground rules and assumptions upon which this model is based are discussed in detail in the Cost Section of this report.

S3 Mission Support Model

SERVICE CATEGORY	PRIMARY MISSIONS		MISSIONS REQUIRING RENDEZVOUS/RETRIEVAL			
			SUPPORT		EARTH RETURN	DEORBIT
YEAR	DEPLOY-MENT	SORTIE	REPAIR	CHANGEOUT RECONFIGURE RESUPPLY		
1983	5	3	1	0	0	0
1984	12	4	1	0	1	0
1985	14	5	3	5	1	1
1986	16	6	4	5	2	1
1987	18	7	7	6	2	1
1988	21	8	8	11	3	1
1989	24	9	11	12	3	1
1990	28	10	12	14	4	1
1991	32	12	14	19	4	1
1992	37	13	16	21	5	1
1993	42	15	18	24	6	0

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Typical S^3 Launch and Flight Operations

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REMOTE CONTROL & CREW EVA SERVICING

Both EVA and remote-control servicing modes are planned. For most of the remote control operations, crew EVA backup is reqired to provide maximum probability of mission accomplishment.

The automated mode is preferred for servicing operations such as rendezvous and dock with satellite, TMS, MTV or OTV.

Because EVA servicing offers a lower-cost approach with minimal S^3 equipment, it is preferred for a large portion of the near term, near orbiter service missions.

Remote Control and Crew EVA Servicing

- SERVICING FUNCTIONS PERFORMED UTILIZING AUTOMATED EQUIPMENT REMOTE-CONTROLLED FROM PRESSURIZED ORBITER AFT FLIGHT DECK
- BACKUP FOR ALL SERVICING PROVIDED BY CREW IVA AND EVA OPERATION
- SELECTED SERVICING PERFORMED WITH EVA AS PRIMARY MODE
- EVA OPERATIONS INCLUDE:

INSPECT/CHECKOUT
- EXAMINE/OBSERVE
- DIAGNOSIS/ISOLATION
- ASSESS/ANALYZE
- ACTIVATE/SELF-CHECK

OVERRIDE
- EXTEND/RETRACT
- OPEN/CLOSE
- LATCH/UNLATCH

SAFING
- UNFASTEN/FASTEN
- INSPECT/VERIFY
- MATE/DEMATE
- ACTIVATE/DEACTIVATE
- SHIELD/COVER

MANEUVER
- TETHER
- STABILIZE
- TRANSFER/TRANSLATE

CHANGEOUT
- REMOVE/REPLACE
- UNFASTEN/FASTEN
- ALIGN/MATCH/INDEX

REPAIR
- REPLACE ITEM
- START/SHUT-DOWN
- APPLY COATING

SERVICING CONCEPTS (TYPICAL)

Three typical servicing concepts are illustrated in this figure.

The Solar Maximum Mission, utilizing the NASA/GSFC MMS modularized spacecraft is acquired by the Orbiter RMS, lowered onto a Flight Support System. Satellite modules can be changed out by a module-exchange machanism aided by crew EVA. EVA may be required prior to RMS grapple to attach a second, optimally located grapple fixture.

The Gallileo space vehicle is mounted on an IUS upper stage, which transfers into planetary trajectory after deployment. The IUS Gallileo is erected by rotation out of the cargo bay; spacecraft and payloads are then checked out. If appendages are extended for a more complete checkout; they must be refolded before deployment and IUS ignition because of the high loads applied by the IUS in attaining earth-escape velocity.

The Space Telescope revisit and service mission uses the DMP to hold the satellite at the proper angle in the cargo bay and rotates it to allow crew access to all circumferential module locations.

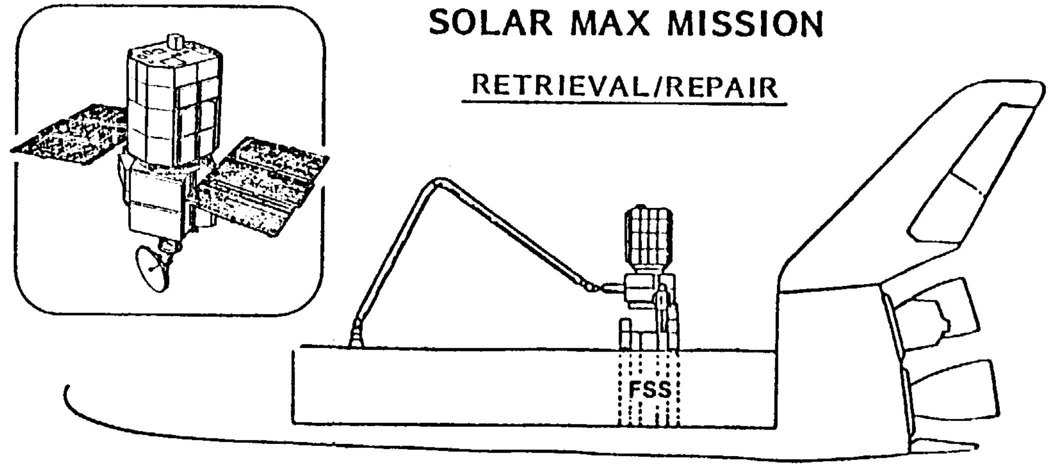
Servicing Concepts (Typical)

S^3 SERVICE FUNCTIONS

- DESPIN/RESPIN
- DEORBIT
- CHANGEOUT/RESUPPLY
- REPAIR
- DEBRIS HANDLING
- CHECKOUT

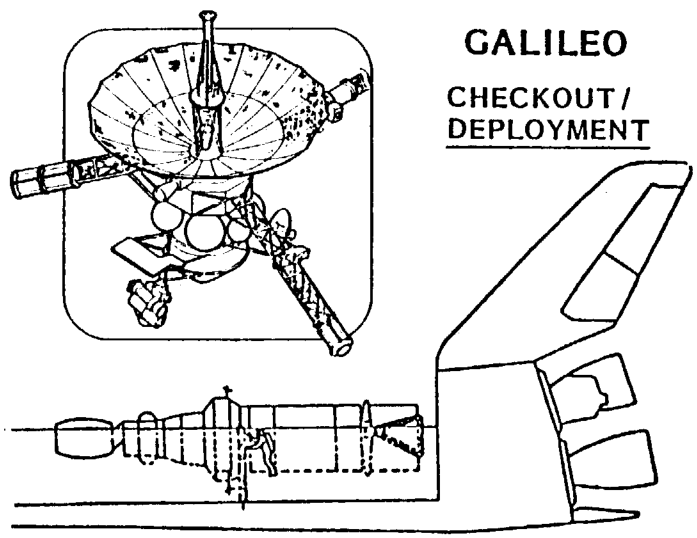
SOLAR MAX MISSION

RETRIEVAL/REPAIR



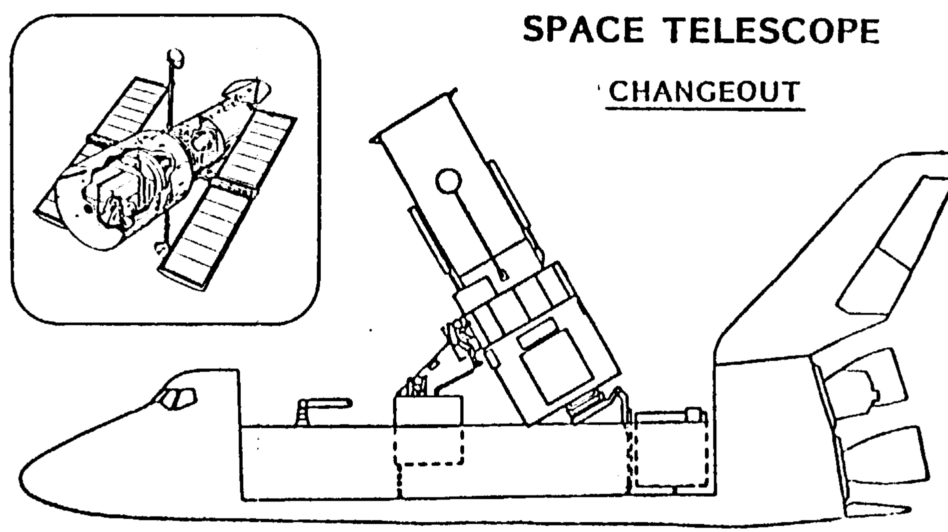
GALILEO

CHECKOUT/
DEPLOYMENT



SPACE TELESCOPE

CHANGEOUT



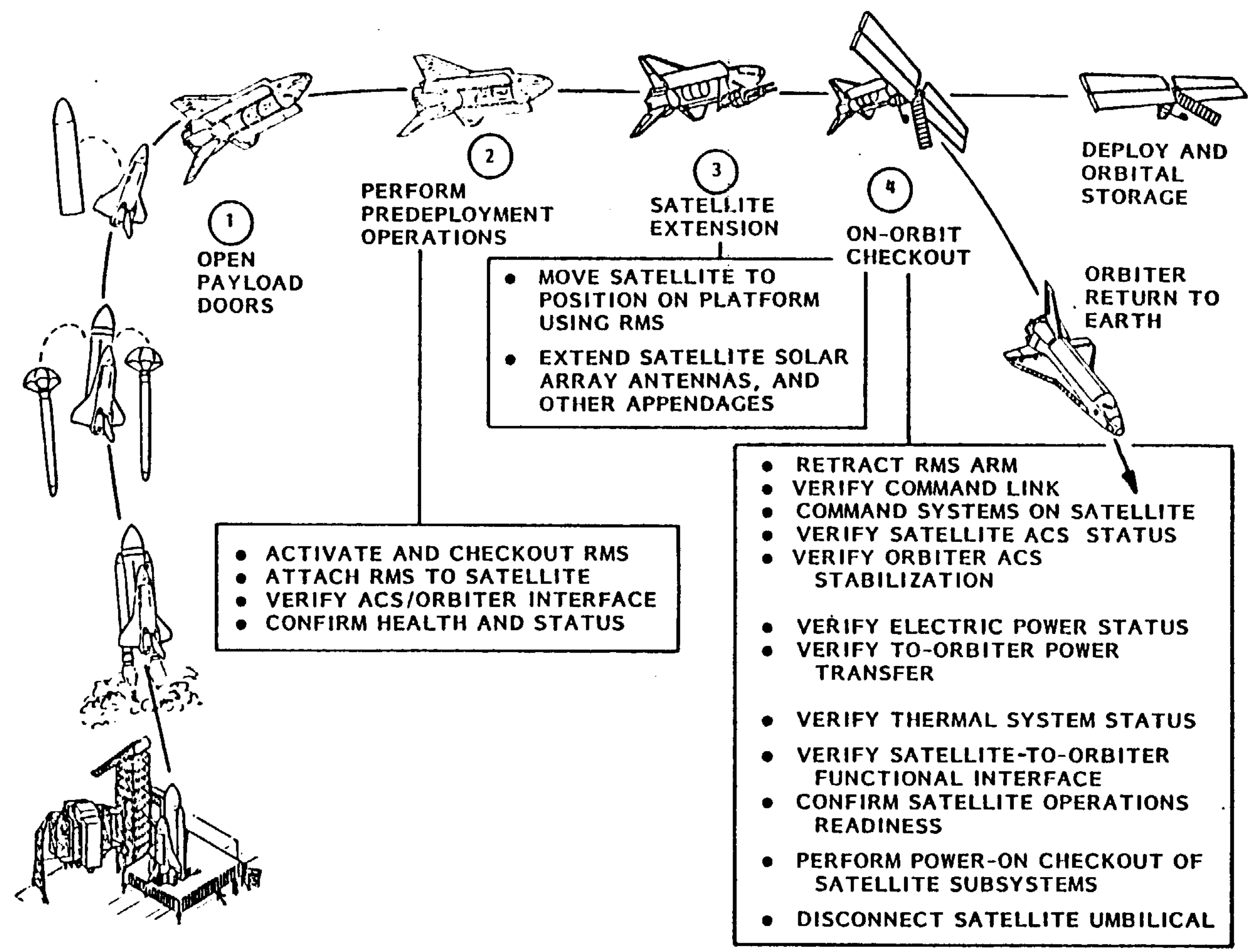
DEPLOYMENT MISSION PROFILE (TYPICAL)

A typical checkout/deployment mission profile is shown here. The predeployment, Satellite extension, and checkout phases are identified and the functions comprising each are listed.

The orbit checkout of the satellite verifies its flight-readiness before final deployment. The Satellite appendages (solar array, antennas, radiators) may be extended while the satellite is still docked to the orbiter or attached to the RMS. This allows end-to-end checkout of the spacecraft and its payload. Detailed checkout is accomplished through the mission POCC; a lesser health check can be done from the orbiter.

The final step in deployment sequence is the separation of satellite from the Orbiter and station-keeping free-flight as final verification of verification of subsystems is made via RF link with the POCC. Functions such as solar array rotation and torquing of spacecraft for attitude control, not posssible in Orbiter-docked mode, are checked. If malfunction is noted, Satellite can be retrieved and repaired on the Orbiter or returned to earth for repair.

Deployment Mission Profile (Typical)



RETRIEVAL/SERVICE/REDEPLOYMENT SEQUENCE

A typical sequence of service functions is shown in this figure. Timelines are generated for each specific mission to establish the total flight timeline, the necessity to extend the orbiter mission duration, and the interfaces with other mission operations requirements.

As the operations planning matures, these sequences are expanded into detail task/activity lists for the Orbiter crew and ground control team. They are used for orbit operations checkoff lists, and preflight training/rehearsal activities.

Retrieval/Service/Redeployment Typical Sequence of Operations (1 of 2)

SATELLITE CONFIGURATION/STATUS VERIFICATION

- DETERMINE CONDITION, MOTION RATES, APPENDAGE ORIENTATION FROM POCC VIA TLM OR DIRECT OBSERVATION (VISUAL OR MTV)

RETRIEVAL READINESS

- DEACTIVATE SATELLITE PROPULSION/ACS, MONITOR CAUTION/WARNING READOUTS ON TELEMETRY LINK VIA POCC OR DIRECT

ORBITER READINESS CHECK

- VISUAL CHECK CARGO BAY, DOOR POSITION
- CHECK RMS FUNCTION
- CHECK DEPLOYMENT AND MAINTENANCE PLATFORM (DMP)

DOCKING

- FINAL APPROACH MANEUVER (PROXIMITY OPERATIONS)
- GRAPPLE SATELLITE
- BERTH TO DMP
- UMBILICAL CONNECT

CHECKOUT/CHANGEOUT RECONFIGURE, RESUPPLY/CHECKOUT

- DIAGNOSTIC CHECKOUT OF SATELLITE
- EVA
- REPLACE ORUs AS REQUIRED AND PREPLANNED
- REPLENISH EXPENDABLES
- CHECKOUT ALL SUBSYSTEMS

Retrieval/Service/Redeployment
Typical Sequence of Operations (2 of 2)

REDEPLOY

- CHECK ORBITER STATUS; DEACTIVATE RCS
- RMS GRAPPLE SATELLITE
- RELEASE HOLD-DOWN LATCHES
- EXTRACT/EXTEND SATELLITE
- DEPLOY APPENDAGES
- RECHECK SATELLITE WITH SOLAR ARRAY AND ANTENNAS OPERATING
- RELEASE UMBILICAL
- RELEASE SATELLITE

STATION-KEEP CHECK

- SAMPLING OF SATELLITE RESPONSE TO RF COMMANDS FROM ORBITER OR VIA POCC
- SATELLITE HEALTH VERIFICATION FROM ORBITER OR VIA POCC

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S^3 Ground Support Operations

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S^3 LAUNCH SITE OPERATIONS

The S^3 equipment and satellite ORU logistic flow is shown combined with the Shuttle launch site processing to create an integrated flow plan. The numerous launch site operational steps are outlined.

The processing and prelaunch checkout of the S^3 equipment is not a constraint upon the Shuttle cycle time from landing to the following launch. The installation and removal of the S^3 equipment kits is a constraint and is carefully planned and coordinated with all other orbiter and user requirements.

The task of preparing the service kits, the coordination of their installation and removal from the orbiter are the responsibilty of the Logistics Division of the Satellite Servicing Organization. The Kit refurbishment, repair and storage is the responsibility of the Space Systems Maintenance Division.

S^3 Launch Site Operations

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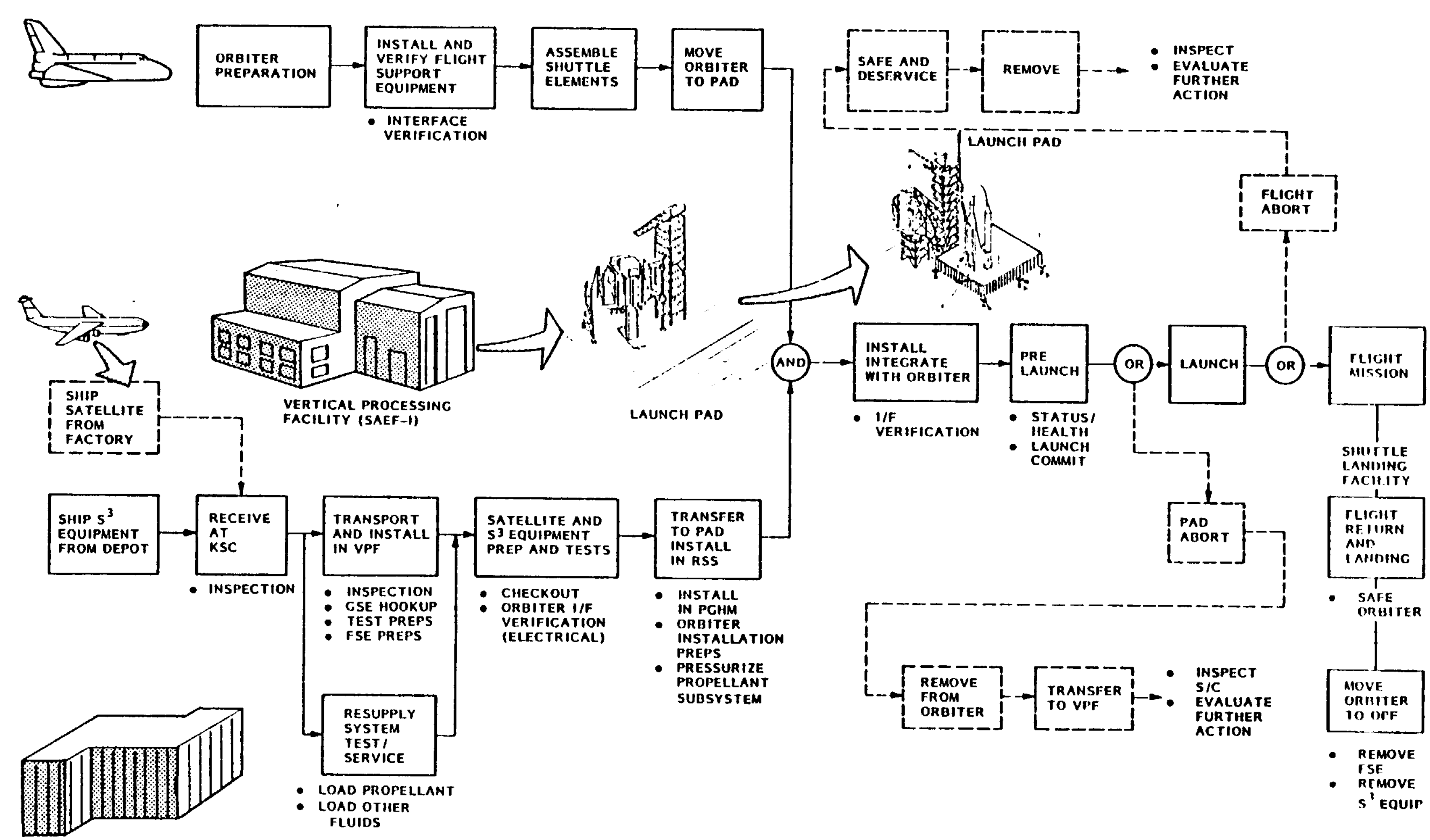

SATELLITE SERVICES OPERATIONS CONTROL CENTER (SSOCC)

Three important functions of the SSOCC are shown together with the corresponding subfunctions.

During satellite service operations, the Flight Operations Control Group operates continuously during all service operations. Realtime displays are continuously monitored. Selected status data and TV are recorded for dissemination to user agencies and other key organizations.

The principal interface with the user agencies is maintained by the Mission Management Group. It coordinates flight operations requirements, crew scheduling and STS scheduling interfaces; this is of particular importance if there are conflicting work assignments for a specially trained flight operations crew. Training and service operations rehersals are also coordinated by the management group.

The Performance Evaluation Group assembles and diseminates data relative to the performance of the Crew, S^3 equipment, and mission operations. It also maintains equipment maintenance records to pin-point weak design features in the equipment.

Satellite Services Operations Control Center (SSOCC)

- SSOCC IS FOCAL POINT OF ALL S^3 MISSION ACTIVITIES, PROVIDING CONTROL OF ORBITAL SERVICING OPERATIONS
- PLANS, SCHEDULES, AND OPERATES THE S^3 FLIGHT SEGMENT

MISSION MANAGEMENT

- TDRS AND DOMSAT AND DSCS SCHEDULE COORDINATION
- GROUND COMMUNICATIONS LINK COORDINATION
- DAILY AND LONG-RANGE S^3 ACTIVITY PLANNING
- MANAGEMENT OF GROUND REFURBISHMENT/SUPPLY DEPOTS FOR S^3
- INTERFACE WITH USERS
- STS SCHEDULE COORDINATION
- CREW SCHEDULING
- CONTINGENCY PLANS FOR NON-NORMAL OPERATIONS

FLIGHT OPERATIONS CONTROL

- COMMAND GENERATION FOR ORBIT OPERATIONS
- DISPLAY OF ORBIT SERVICING DATA:
  - TV
  - CRT OF TELEMETRY STATUS READOUTS
- REALTIME MONITOR OF ORBIT OPERATIONS
- PROCESS TLM DATA
- FLIGHT DYNAMIC ASSESSMENT:
  - SATELLITE DOCKING
  - TMS FREE-FLY
  - MTV FREE-FLY
- STATUS INFORMATION DISSEMINATION (REALTIME)

PERFORMANCE EVALUATION

- PROBLEM INVESTIGATION
- SATELLITE DIAGNOSTICS EVALUATION FOR SERVICE OPERATIONS SCHEDULING (REPAIR KITS, SPARE ORUs)
- SUMMARY TROUBLE/FAILURE REPORTS
- REPAIR/REFURBISH TREND DATA AS BASE FOR SCHEDULING PERIODS OF REVISIT

SERVICE SIMULATION AND CREW TRAINING

To ensure error-free and effective servicing of space vehicles, rigorous ground simulation and crew training is planned. As new satellites and more sophisticated service equipment are brought into the inventory, crews are retrained.

Simulation is not limited to crew EVA operations. Completely automated servicing modes are duplicated to maximum possible extent using prototype hardware adapted to simulation or using specially designed simulator.

TV recording is used to study and improve the specific operations. Step-by-step flight checklists are generated to guide the actual crew on orbit.

Contingency-mode operations, developed in detail, reduce the "unexpected" space operations to a minimum. An overriding mode is the use of crew EVA for backup of all automated operations (except the remote operations to be performed by the TMS or OTV).

The Crew Systems Division of the Satellite Services Organization has the responsibility for defining and conducting Simulation and Training Programs.

Service Simulation and Crew Training

PROVIDE FOR:

- TESTING SATELLITE INTERFACES WITH S^3 EQUIPMENT
- DESIGN OF SATELLITE SIMULATOR
- DESIGN OF ADDITIONAL OR MODIFIED S^3 EQUIPMENT
- GROUND REHEARSAL OF SERVICE OPERATIONS
- VERIFICATION OF TIMELINES FOR ORBIT OPERATIONS (SIMULATION)
- VERIFICATION OF CREW INTERFACE WITH S^3 EQUIPMENT

TYPICAL SIMULATIONS – AUTOMATED AND CREW (EVA):

- SATELLITE CHECKOUT
- SATELLITE APPENDAGE EXTEND/RETRACT/JETTISON (EVA)
- CHANGEOUT (MODULE REPLACEMENT)
- SATELLITE DEPLOYMENT/RETRIEVAL
- RMS AND END EFFECTOR OPERATION
- COMMON REPAIRS

TYPICAL CREW TRAINING:

- EQUIPMENT MOVEMENT-ZERO "G" HANDLING OF SATELLITES, ORUs, DEBRIS, ETC.
- REMOTE CONTROL OPERATIONS – SIMULATE CONTROL OF MTV, TMS, RMS, ETC.
- ILLUMINATION – VISIBILITY AUGMENTATION
- SAFETY – HAZARD AVOIDANCE

SUPPLY, REPAIR, REFURBISH DEPOTS

These functional depots may or may not be colocated. It is assumed that all functions are performed in one facility located at the launch base. While this appears to be an optimum location, other factors may dictate separating the activities functionally and/or geographically.

The responsibility for the depots falls under the Satellite System Maintenance Division of the SSO. It has a strong intimate interface with the logistics Division.

The Depots are primarily concerned with supply and maintenance of the Satellite Service Equipment. However, they are the natural choice for performing th repair/refurbishment of Orbit Replaceable Units if the manufacturer is not under contract to perform these functions or is unable to do so.

Supply, Repair, Refurbish Depots

S^3 EQUIPMENT AND EXPENDABLES

- MAINTAIN SUPPLY OF FLIGHT-READY EQUIPMENT AND EXPENDABLES
- REPAIR FLIGHT-RETURNED EQUIPMENT, AS REQUIRED
- REFURBISH FLIGHT-RETURNED EQUIPMENT
- SUPPLIER INTERFACE MANAGEMENT

ORBIT REPLACEABLE UNITS

- TRANSHIP FLIGHT-RETURNED UNITS TO SUPPLIER FOR REWORK
- REPAIR/REFURBISH UNITS HAVING NO PRODUCTION/MAINTENANCE SUPPLIER
- MANAGE TURN-AROUND CYCLE AND INVENTORY

S^3 Operations Planning Documentation

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S^3 OPERATIONS PLANS

Two types of Operations Plans are identified and separated in time. The generic mission plans can be generated at the time a clear definition of responsibilities is achieved.

The specific mission plans are generated after manifesting is firm and far enough in advance of the flight date to permit accomplishment of the defined simulations and training. It must also be in time to support facilities scheduling and launch base operations planning.

The Satellite Servicing Orgnaization is responsible for the preparation of these plans and the coordination with all affected organizations and functions. Approvals are anticipated to be required by at least the Mission Planning and Analysis Division and the Flight Operations Panels. Coordination sign-off's are probably required by other associated organizations.

S^3 Operations Plans

GENERIC MISSION PLANS – CAN BE GENERATED NOW

- DEPLOY
- SORTIE
- REPAIR
- CHANGEOUT
- RECONFIGURE
- RESUPPLY
- EARTH RETURN
- DEORBIT

SPECIFIC MISSION PLANS – PREFLIGHT GENERATED/FORMALIZED/APPROVED

- o SOLAR MAXIMUM
- o SPACE TELESCOPE
- o LDEF
- o - - - - -
- o - - - - -

S^3 OPERATIONS PLANS CONTENT

The outline shown on this and the following table indicates the principal factors that must be contained in a complete Operations Plan. The outline serves both for the generic mission plan and for the specific mission plan.

The Satellite Servicing Organization is responsible for the prepration of these plans and the coordination with all affected organizations and functions. Approvals are anticipated to be required by at least the Mission Planning and Analysis Division and the Flight Operations Panels. Coordination sign-off's are probably required by other associated organizations.

S^3 Operations Plans Content

RESPONSIBILITY DEFINITION

- SATELLITE SERVICE ORGANIZATION
  - SSOCC
  - LOGISTICS
  - PLANNING INTERFACE MANAGEMENT
- JSC MISSION CONTROL
- CREW SYSTEMS
- USER
- KSC OR VAFB
- JPL MISSION CONTROL
- SOC

SERVICE SYSTEM REQUIREMENTS

- HARDWARE
  - FLIGHT
  - SUPPORT
- SOFTWARE
- COMMUNICATIONS AND DATA HANDLING
- FLT CREW SIMULATION AND TRAINING
- MOCKUPS AND SIMULATORS
- PIP AND FLT DATA FILE(S)
- ORBITER TO P/L ICDs AND IRDs
- POWER
- PURGE AND/OR CONDITIONING
- HAZARDS/SAFETY AND MONITORING
- TEST OR FUNCTION VER/MONITORING
- EXPENDABLES
- MISSION AND FLIGHT INTEGRATION
- LOADS AND ENVIRONMENT
- ETC

S^3 Operation Plan Content (Contd)

IN-FLIGHT SERVICE TIMELINE

- PRIMARY
- WORK-AROUND

SSOCC FLIGHT SUPPORT

- MANNING REQUIREMENTS
- EQUIPMENT REQUIREMENTS

CREW SYSTEMS

- READINESS VERIFICATION
- TRAINING FACILITY SCHEDULE REQUIREMENTS

LOGISTICS SUPPORT

- REPAIR/REFURBISHMENT PLAN
- INSTALL/REMOVE TIMELINE

FACILITY USE REQUIREMENTS

- DOCUMENTATION

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4. System Cost Estimate

NASA

Satellite Services System Cost Estimate

- OVERVIEW
- SERVICE SYSTEM MISSION MODEL
- SERVICE EQUIPMENT KIT DEFINITION
- AVERAGE MISSION RECURRING COSTS
- PRORATION OF FIXED COSTS
- TOTAL PROGRAM RESOURCE REQUIREMENTS

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NASA

Satellite Services System Cost Estimate

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SYSTEM COST OVERVIEW

Seven Generic Missions were defined in the course of the SSSA Study Part II. These missions are generalizations of the real planned STS missions that are candidates for in-orbit service. To arrive at a total system cost, averages were used in terms of equipment carried, time spent in orbit, the number of EVA's, etc. The total mission model was based on assumptions on the frequency of need of revisit, and the numbers of spacecraft designed for in-orbit service.

The compliment of service equipment required to support the total mission model was defined and the cost of procuring that equipment estimated using a parametric approach (The RCA "RRICE" Model).

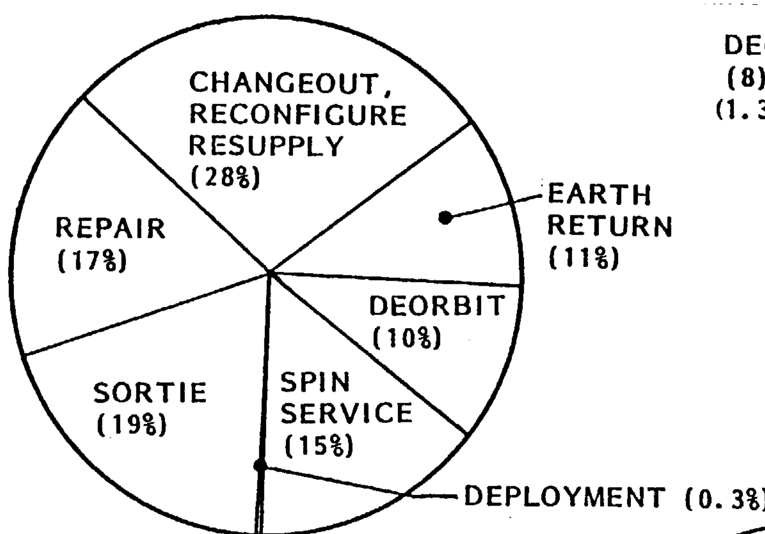
The unit service event cost to the user was estimated by prorating the cost of the service equipment, adding the STS costs (shared cargo, time in orbit, payload special lists, etc.). The total cost to the users was then derived from the unit service event costs multiplied by the number of such events predicted by the mission model in the time frame of 1983-1993.

The results are shown in this chart. The first pie figure indicates the proration of the service system hardware costs. This is the funding requirements for NASA to establish the needed equipment inventory. The second shows the distribution of the service mission types in the whole mission model. The third shows the system user cost breakdown to the generic missions.

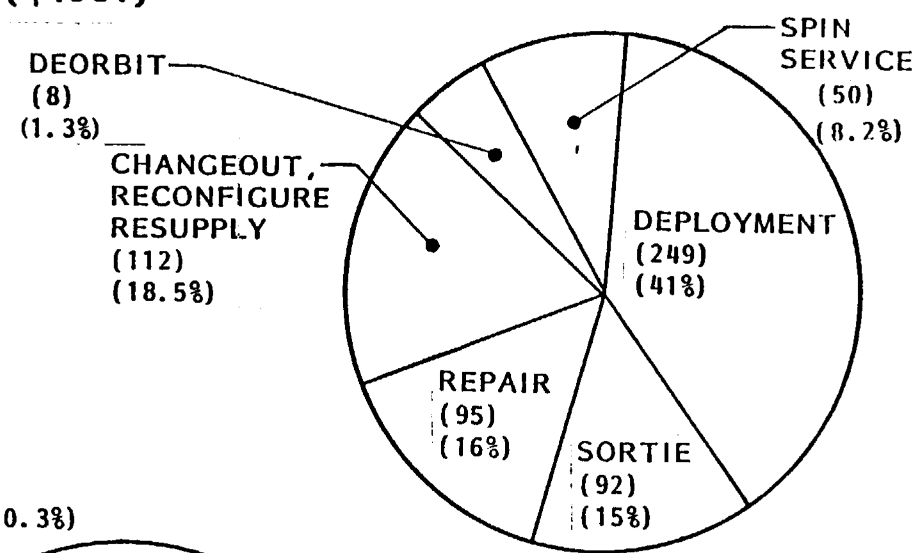
System Cost Overview

1983 - 1993

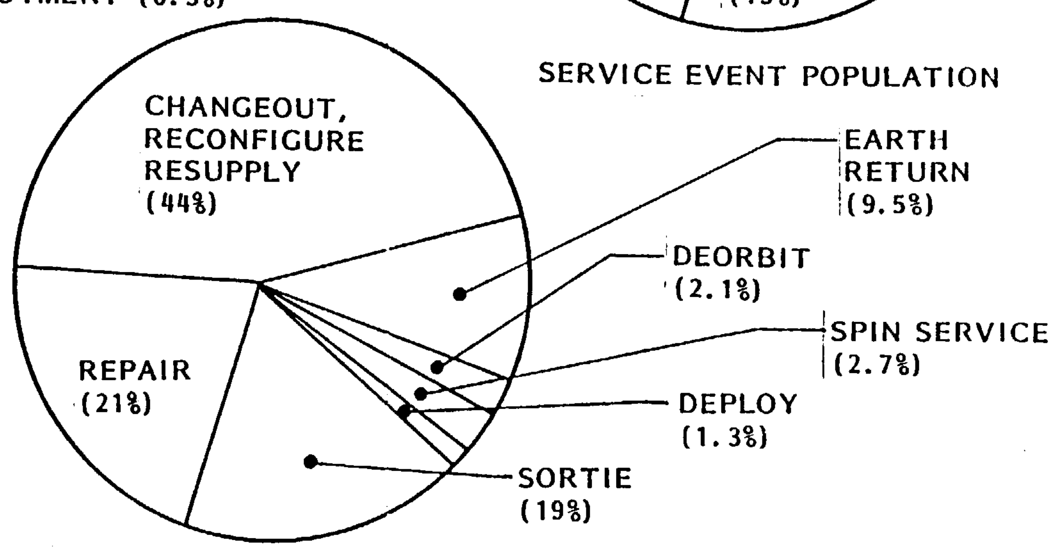
($1981)



PRORATED HARDWARE COST
($205M THROUGH 1987)



SERVICE EVENT POPULATION



TOTAL USER COST BREAKDOWN ($2.12B)

SYSTEM LEVEL COST ELEMENTS

The elements that were included in and excluded from the system cost estimates are indicated in this chart. The RCA "PRICE" model includes the DDT&E, program management, test, integration etc., for each of the 66 identified equipments that make up the service kits. Other costs are derived from the STS Cost Reimbursement guide and experience factors for similar programs.

The cost factors that were found to be intractable at this time are listed on the right. The assumption was made that the STS Orbiter could rendezvous with those satellites which are free flyers either because they utilize one of the STS standard orbits or are capable of returning from their operational orbit to the orbiter by antonomous means or through the action of another stage (e.g., TMS).

System Level Cost Elements

INCLUDED IN COST ESTIMATE	INSUFFICIENT DEFINITION FOR INCLUSION
SERVICE KIT EQUIPMENT DDT&E PRODUCTION AGE/STE SUPPORT SOFTWARE REFURBISHMENT SPACE TRANSPORTATION SHARED LAUNCH CHARGE INSTALL/REMOVE TIME ON-ORBIT SUPPORT TIME EVA PAYLOAD SPECIALIST SIMULATION AND TRAINING PROGRAM MANAGEMENT SYSTEM ENGINEERING AND INTEGRATION FACILITIES	OMS KITS COMMUNICATIONS FOR FLIGHT OPERATIONS DELIVERABLE SOFTWARE MISSION DATA PROCESSING AND REPORTING GROUND SUPPORT OF FLIGHT OPERATIONS

SYSTEM LEVEL COST METHODOLOGY

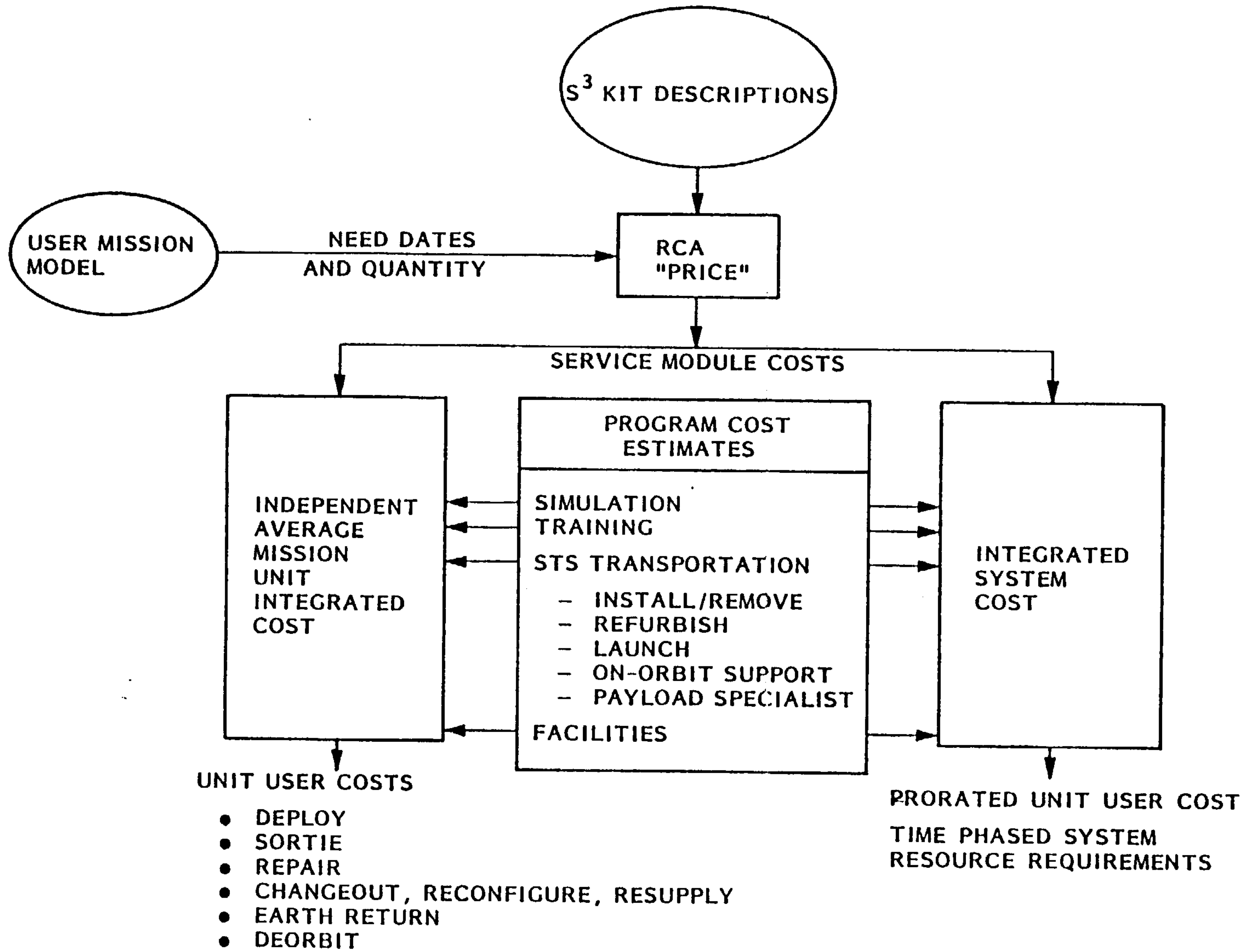
This figure represents a road map to the costing activity. The S^3 kits were defined to provide the needs of the seven generic mission functions. These kits are made up of 66 separate hardware items. This data was input to the RCA "Price" model together with the kit need dates and quantities. The output provided the time phased hardware costs for each service kit.

The costs were convolved in two ways. Shown on the left is the cost to the user <u>as if</u> the satellite service system were dedicated to performing one and only one service function. This separation into independent function cost gives an indication of the costs that could be incurred by separate space programs mechanizing their service needs rather than centralizing the function.

The right hand block indicates the accumulation of costs if all service functions are provided by a centralized organization.

The central block indicates those cost elements involved which are over and above the hardware costs.

System Level Cost Methodology



NASA

Satellite Services System Cost Estimate

- OVERVIEW
- SERVICE SYSTEM MISSION MODEL
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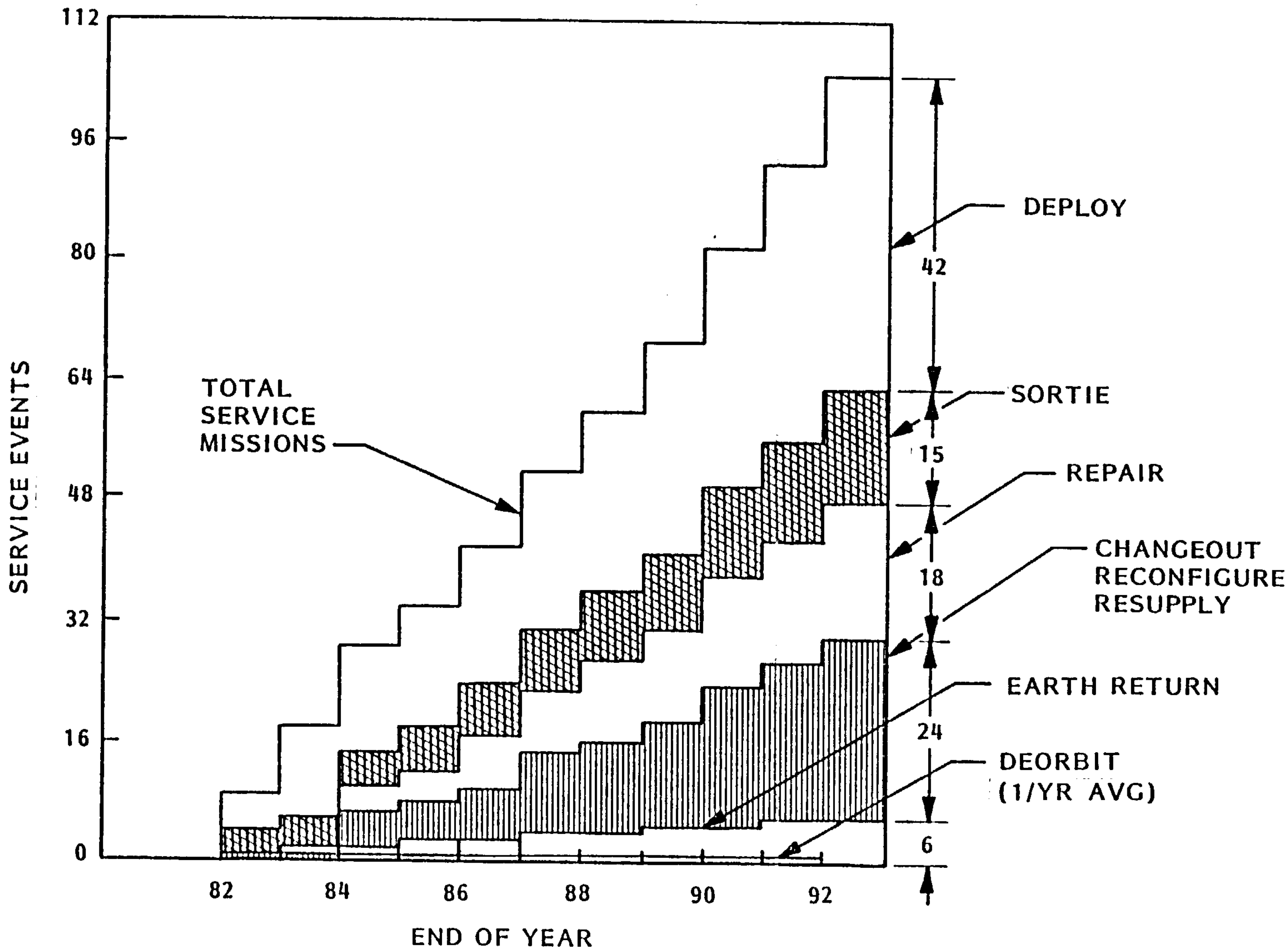
SATELLITE SERVICE SYSTEM MODEL

This composite graph shows the mission model that was generated using the data and assumptions presented on the following two charts. This is an aggregate chart with the top line indicating the sum total of all constituents. The individual service event quantities for the year 1993 are included on the right hand border to indicate the cumulative nature of the chart.

The total events identified for th 1983 through 1993 time frame is 637.

Satellite Service System Model



SERVICE OPPORTUNITY MISSION MODEL DEVELOPMENT

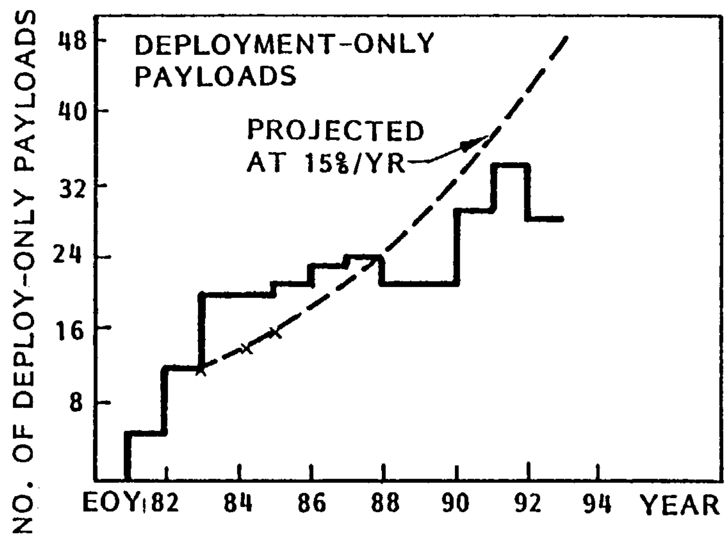
The mission model was based on the NASA STS Mission Model (Reference A in the figure). It was modified in the following ways:

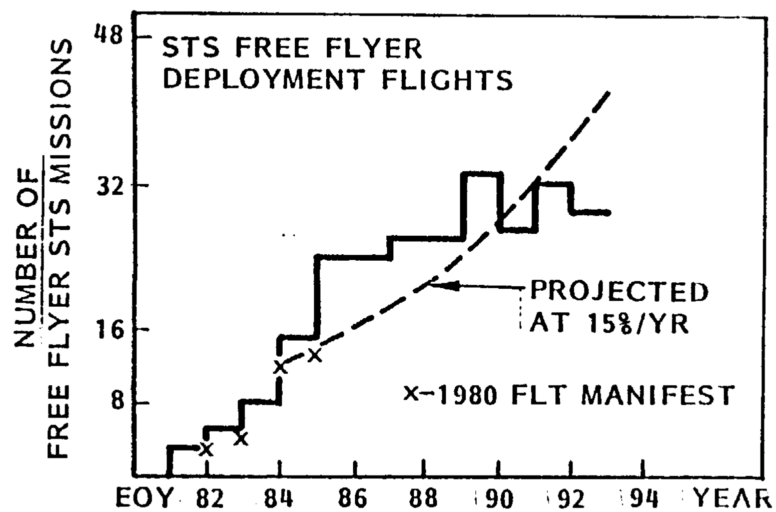
1. The year of operation was slipped to accommodate the STS delay.
2. The current flight manifests were over plotted to update the original data to current planning.
3. A growth rate beyond the limits of the current flight manifests was used to reflect expectation in the era where mission planning is not well defined.

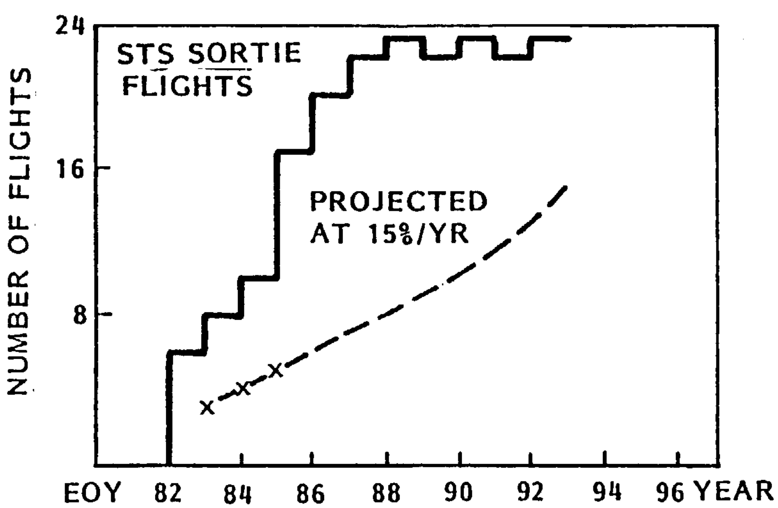
The model represents an estimate of the total space missions in the STS era and is not yet related to Satellite Service events.

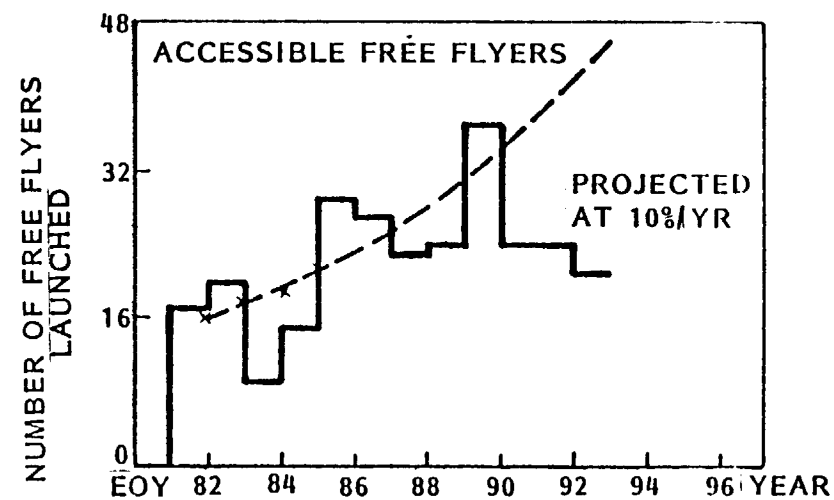
Service Opportunity Mission Model Development

NASA LOCKHEED









SERVICE EVENT AND KIT ASSIGNMENT MODEL RATIONALE

To define the opportunities for Satellite Services, a number of assumptions were made for each generic mission defined in the mission model.

For the Deployment and Sortie Missions it is assumed that single opportunity nature of these missions require that the service equipment and the trained crew to execute the service is carried on every flight of these categories.

The number of Repair service opportunities was derived based on the assumption that 5% of new deployments and 10% of free flyers in service 3 or more years will require repair. For this and the following categories, the mission is preplanned, i.e., the specific repair equipment kit and flight timeline are part of the preflight missions operations plan. It is a corrallory that "unplanned" repair is not a part of the service event model because such activity depends completely on the exigencies of the specific situation, the tools available, and the ingenuity of the crew.

The CR&R function is assumed to be required on the cumulative satellite population that have seen 3 years of service since launch or since last Changeout, Reconfiguration, or Resupply (CR&R).

The Earth Return assumption is that 4% of the STS launched and accessible free flyers are designed for or are of sufficient importance to require retrieval and return to earth in the Orbiter Cargo Bay.

The Deorbit function if not likely to be important in the time frame of interest for collision avoidance purposes. Controlled re-rentry of decaying satellites is more significant but expected to be low in number. The assumption of 1% of the low altitude population leads to a requirement of approximately one event per year through 1992.

The assumptions made here-in are judgemental in nature and equally valid assumptions could result in significant shifts in the service mission model.

NASA LOCKHEED

Service Event and Kit Assignment Model Rationale

DEPLOYMENT SORTIE	• NASA STS MISSION MODEL MODIFIED BY CURRENT FLIGHT MANIFESTS AND DoD MISSION MODELS; PROJECTED AT 15 PERCENT YEARLY GROWTH RATE – EACH FLIGHT CONSTITUTES A SERVICE OPPORTUNITY NECESSITATING INCORPORATION OF SERVICE KIT
REPAIR	• FIVE PERCENT OF INITIAL DEPLOYMENT PAYLOADS PLUS • TEN PERCENT OF ACCESSIBLE FREE FLYERS IN SERVICE FOR THREE OR MORE YEARS (PRE-STS LAUNCHES EXCLUDED) – SERVICE KITS ONLY CARRIED FOR SCHEDULED REPAIR TASKS
CHANGEOUT RECONFIGURE RESUPPLY	• THIRTY PERCENT OF ACCESSIBLE FREE FLYERS IN SERVICE FOR THREE YEARS WITHOUT CR&R SERVICE • SERVICE INTERVAL = 3 YEARS – SERVICE KIT SELECTED FOR SPECIFIC MISSION REQUIREMENTS
EARTH RETURN	• FOUR PERCENT OF ALL FREE FLYERS LAUNCHED BY STS • INTERVAL BETWEEN REPLACEMENT AND RETURN = 2 YEARS – SERVICE KIT IS TAILORED TO SATELLITE REQUIREMENTS
DEORBIT	• ONE PERCENT OF ALL FREE FLYERS LAUNCHED BY STS PLUS • ONE PERCENT OF PRE-EXISTING FREE FLYERS BELOW 600 KM – SPECIFIC SERVICE KIT CARRIED TO MATCH MISSION PARAMETERS

NASA

Satellite Services System Cost Estimate

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SERVICE KIT DEFINITION DEVELOPMENT

Examination of the service functions and mission scenarios led to the identification of 66 hardware items needed to meet the user requirements under the ground rules governing the study (near orbiter, and 1983-93 time frame). These hardware items were grouped into 18 functional modules which can be thought of as the logistics building blocks for the service missions. The six generic service missions were identified as having an associated service kit made up of one or more of the modules. Particular mission requirements will dictate a variation of the generic kits, but for the purposes of cost estimating an average kit was defined and used for each member of the class.

Service Kit Definition Development

66 IDENTIFIED SERVICE EQUIPMENTS
EXISTING, MODIFIED, OR NEW

⇩

18 FUNCTIONALLY RELATED
SERVICE EQUIPMENT MODULES

⇩

SIX SERVICE KITS

ONE EACH FOR SIX GENERIC MISSIONS

- DEPLOYMENT
- SORTIE
- REPAIR
- CHANGEOUT, RECONFIGURE, RESUPPLY
- EARTH RETURN
- DEORBIT

SERVICE MODULE DEFINITION SHEET

This chart indicates how the 18 modules were identified as groups of the 66 service equipments. This example shows the definitions of modules "A" an "B" (right hand column). These sheets were generated for all the equipment with the important parameters identified that were important to the cost estimation. As indicated, the module A is a grouping of STS Standard hardware that is useful to all service missions. Since it is standard equipment, its mass and volume are not pertinent and the cost of the equipment itself and its transportation into orbit are not included in the system costs. Module B is representative of the remainder of the modules and indicates the data generated to support the cost estimation.

Modules A and B constitute those equipments which are needed for single "unplanned" services and are planned for manifesting on each STS flight.

Service Module Definition Sheet

REPRESENTATIVE

EQUIPMENT	QTY	UNIT MASS/WT (kG/LB)	INSTALLED OR STOWED LOCATION	EQUIPMENT PARAMETERS SIZE mm/IN. STOWED	INSTALLED	USE VOLUME	MODULE I.D.
TETHERS* (2 FOR P/L)	2	N/A	MIDDECK-AIRLOCK	N/A			A
EMU*	2	N/A	AIRLOCK	N/A			A
HELMET LIGHTS/BAT.*	4	N/A	AIRLOCK	N/A			A
TOOL CADDY*	2	N/A	MIDDECK-AIRLOCK	N/A			A
PORTABLE LIGHT*	2	N/A	MIDDECK-AIRLOCK	N/A			A
RATCHET WRENCH	2	0.75 (1.5)	CARGO BAY	300 x 200 x 60 (12 x 8 x 2 1/2)			B
POWER TOOL/BAT.	1	6.7 (13.5)	CARGO BAY	280 x 300 x 150 (11 x 12 x 6)			B
CUTTERS	1	0.5 (1)	CARGO BAY	180 x 25 x 75 (7 x 1 x 3)			B
FOOT RESTRAINT	2	8.9 (18)	CARGO BAY	3100 x 460 x 230 (22 x 18 x 9)			B
TOOL STOW PALLET	1	5.4 (11)	CARGO BAY	1070 x 610 x 75 (42 x 24 x 3)	1120 x 660 x 355 (44 x 26 x 14)	1070 x 610 x 1220 (42 x 24 x 48)	B
SHP CORNER/EDGE KIT	1	3.7 (7.5)	CARGO BAY	300 x 300 x 250 (12 x 12 x 10)			B
SAFEING KIT/TOOLS	1	1.7 (3.5)	CARGO BAY	200 x 300 x 250 (8 x 12 x 10)			B

SERVICE KIT SYNTHESIS FROM SERVICE MODULES

The 18 modules are listed in the first column of this chart. A descriptive title is given to identify the purpose.

The right side shows the applicability of the module to the six generic mission service kits.

A seventh mission functional kit was identified as Spin Service which is required when the satellite to be serviced is spin stabilized. However, the spin service kit is not a separate entity for manifesting as it is only used in conjunction with one of the other service kits.

It is recognized that specific missions may not require the full complement of modules, but as a generalization this chart indicates the recommended service hardware.

Service Kit Synthesis From Service Modules

MODULE DESIGNATOR	MODULE TITLE	SERVICE KITS: DEPLOY	SORTIE	REPAIR	CHANGEOUT RECONFIGURE RESUPPLY	EARTH RETURN	DEORBIT	SPIN SERVICE
A	STD ORBITER PROVIDED CREW AIDS	●	●	●	●	●	●	
B	UNSCHEDULED SERVICING CREW AIDS	●	●	●	●	●	●	
C	DESPIN DEVICE							●
D	MOUNTING PALLET AND DESPIN ATTACH ELEMENTS						●	●
E	COMMAND/COMMUNICATION/SIGNAL UNIT						●	●
F	DEORBIT DEVICE						●	
G	SPARES AND DEBRIS CONTAINER		●		●	●		
H	MODULE TRANSFER MECH AND WORK STATION		●		●			
I	CLOTHESLINE AND SERVICE TRAY		●		●			
J	MISCELLANEOUS SERVICING AIDS		●	●	●		●	
K	FLUID TANKAGE AND TRANSFER DEVICES		●	●	●			
L	SERVICE AID STOWAGE PALLET		●		●			
M	DEPLOYMENT MAINTENANCE PLATFORM		●	●	●	●		
N	REPAIR SERVICING AIDS		●	●	●	●		
O	REPAIR KIT STOWAGE PALLET		●	●	●	●		
P	RESPIN DEVICE						●	●
Q	DEBRIS HANDLING SERVICING AIDS AND PALLET					●	●	
R	MMU AND STATION					●	●	

SERVICE MODULE QUANTITY AND NEED DATES

The quantity and first need dates are given for each of the service equipment modules. The first need date corresponds to the first scheduled service event which is identified in the service model. The second and subsequent need dates are based on the growth of traffic and the need at VAFB as well as KSC. It was assumed that a single module would serve all the traffic from one launch base until the service events using a given module grew to 10 per year. Below this number it was assumed that a module could be off loaded from one orbiter and made available to the next using flight. At a demand rate of 20/year it was postulated that a module of each type would be dedicated to each of the orbiters and that a spare would be held in the supply depot at each launch base: a total complement of 6 units.

Expendables are provided for each service event. The deboost motors and guidance stage is the only expendable hardware identified.

Service Module Quantity and Need Dates

MODULE DESIGNATOR	MODULE TITLE	PRODUCTION QUANTITY(1)	FIRST NEED DATE
A	STD ORBITER PROVIDED CREW AIDS	6	83
B	UNSCHED SERVICING CREW AIDS	6	83
C	DESPIN DEVICE	4	84
D	MOUNT. PALLET AND DESPIN ATTACH ELEMENTS	4	84
E	COMMAND/COMMUNICATION/SIGNAL UNIT	6	84
F	DEORBIT DEVICE	8*	85
G	SPARES AND DEBRIS CONTAINER	6	83
H	MODULE TRANSFER MECH AND WORK STATION	6	83
I	CLOTHESLINE AND SERVICE TRAY	6	83
J	MISCELLANEOUS SERVICING AIDS	6	83
K	TANKAGE AND TRANSFER DEVICES	6	83
L	SERVICE AID STOWAGE PALLET	6	83
M	DEPLOYMENT MAINTENANCE PLATFORM	6	83
N	REPAIR SERVICING AIDS	6	83
O	REPAIR KIT STOWAGE PALLET	6	83
P	RESPIN DEVICE	6	84
Q	DEBRIS HANDLING SERVICING AIDS AND PALLET	4	84
R	MMU AND STATION	4	84

[1]MORE THAN 20 SERVICE EVENTS PER YEAR REQUIRES FULL COMPLEMENT OF KIT HARDWARE, I.E., 1 PER ORBITER AND 1 SPARE EACH KSC AND VAFB = 6 TOTAL

*EXPENDABLE – ONE PER SERVICE EVENT

AVERAGE SERVICE EVENT PARAMETERS

This chart provides the details of the service kits defined for the average generic service event. The deployment kit has a mass of 26 Kg and would require an added day on orbit if a service event were necessary. Since the service model assumed a need at 5% of the deployments flown, the average chargeable on-orbit time would be 0.05 days and the average EVA's are also 5%. This rationale accounts for the non integral factors shown in the table. The need for servicing on the SORTIE missions cannot extend the mission because the total endurance of the STS is planned and charged to SORTIE payloads.

The EVA events are likely to be one or two depending on the complexity of the service event. There are expected to be relatively few uses of the MMU and rather than spread a small fraction across the several missions, it was identified as used on each of the Earth Return and Deorbit missions. Similarly the cost of the payload specialist who might be needed on any one of the missions, was assigned to each of the Repair and CR&R missions.

The install/remove time spans were estimated from the complexity of the equipment involved.

Average Mission Service Event Parameters

MISSION SERVICE FUNCTION	SERVICE KIT		ON-ORBIT SUPPORT	EVA EVENTS/MMU USES	PAYLOAD SPECIALIST		INSTALL/ REMOVE TIME
	MASS (kg)	'WEIGHT (lb)	(DAY)	# / #	MASS (kg)	WT (lb)	(HR)
DEPLOY	26	(57)	0.05	0.05/0	0	0	0/0
SORTIE	1803	(3975)	0.0	1/0	0	0	10/5
REPAIR	986	(2174)	2.5	1.5/0	120	(242)	6/3
CR AND R	2372	(5230)	3.0	1.5/0	120	(242)	11/5.5
EARTH RETURN	1960	(4320)	2.0	1/1	0	0	12/5
DEORBIT	630	(1387)	2.0	1/1	0	0	5/2
DESPIN/RESPIN	216	(477)	N/A	N/A	0	0	2/1

MISSION ON-ORBIT SERVICE TIME CHARGEABLE TO SSS USER

This chart presents the rationale for estimating the number of EVA operations required for each service event on-the average. The essential ground rule used in establishing the stay time is that the time involved in preparing for executing, and post operations EVA occupies a complete work cycle and essentially requires an added day on orbit. The performance of an EVA also precludes return to earth on that day, resulting in the reentry day also being charged to the Satellite Service user.

Mission On-Orbit Service Time Chargeable to SSS User

MISSION CLASS	NO. EVA OPERATIONS	ON-ORBIT TIME (DAYS)	GROUND RULES
DEPLOY (95%) (5%)	0 1	0 1	SERVICE FOR DEPLOYMENT ONLY MISSION CONSISTS OF SIMPLE FIXES OR EARTH RETURN OF 5% OF PAY LOADS EXPERIENCING INITIAL FAILURE
SORTIE	1	0	SORTIE MISSIONS MAKE FULL USE OF ORBITER ENDURANCE. SERVICE CANNOT EXTEND ORBIT TIME
REPAIR	1-2	2-3	MAXIMUM CASE REQUIRES SATELLITE ATTITUDE STABILIZATION AND BERTHING IN FIRST EVA; REPAIR, CHECKOUT, REDEPLOY IN SECOND
CHANGEOUT RECONFIGURE RESUPPLY	1-2	2-4	MAXIMUM CASE = SPACE TELESCOPE MAINTENANCE TIMELINE MINIMUM CASE = MMS SERVICE FROM STABILIZED INITIAL CONDITION
DEORBIT	1	2	SINGLE EVA TO MATE DEBOOST STAGE, DEPLOY, BACK OFF, AND COMMAND
EARTH RETURN	1	2	STABILIZATION OF SPACECRAFT, BERTHING, STOW IN 1 EVA

*STAY TIME PRESUMES NO MISSION SHARING, I.E., RETURN DAY IS CHARGED TO SERVICE MISSION

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Satellite Services System Cost Estimate

- OVERVIEW
- SERVICE SYSTEM MISSION MODEL
- SERVICE EQUIPMENT KIT DEFINITION
- $\boxed{\text{AVERAGE MISSION RECURRING COSTS}}$
- PRORATION OF FIXED COSTS
- TOTAL PROGRAM RESOURCE REQUIREMENTS

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△ RECURRING USER SERVICE COSTS

On the basis of the foregoing charts, the recurring charges to the S^3 user are given in this table.

The cost for all the recurring items are drawn from the STS Cost Reimbursement Guide. The STS charge is a weighted average of the charges/lb for launching a payload into low and high inclination orbits.

Kit refurbishment charge is an experience number which varies between purely mechanical equipment and the more complex electro-mechanical.

The recurring costs given here are those costs incurred for the service operations and are over-and-above the basic payload and mission operations cost.

△ Recurring User Service Costs*

STS SUPPORT (1981 $K)

AVERAGE MISSION	INSTALL AND REMOVE COST ($K)	ON-ORBIT SUPPORT COST ($K)	EVA COST ($K)	PAYLOAD SPECIALIST TRAINING ($K) TRANSPORT ($K)	SPACE TRANSPORTATION AT $910/LB	S^3 KIT REFURB AT $10.0/LB MECH $14.6/LB ELECT	TOTAL RECURRING
DEPLOY	0	27	5	N/A	52	0	84
SORTIE	250	0	60	N/A	3617	47	3974
REPAIR	268	1339	161	134/220	2199	27	4348
CHANGEOUT RECONFIGURE RESUPPLY	491	1607	161	134/220	4980	62	7435
EARTH RETURN	505	1071	179	N/A	3931	52	5738
DEORBIT	209	1071	179	N/A	1262	16	2737
SPIN SERVICE	89	INCL	INCL	N/A	434	5	528

*OVER AND ABOVE PRIMARY MISSION COST

SSS
NASA

Satellite Services System Cost Estimate

- OVERVIEW
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- TOTAL PROGRAM RESOURCE REQUIREMENTS

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S^3 HARDWARE COST PRORATED BY MISSION TYPE

The hardware costs were generated by applying the RCA "PRICE" model to the individual equipment descriptions and then summing by the module complements. The results are presented here in the first row which indicates a total system cost of $205M in 1981 dollars. This row and sum represents procurement of the total quantity of modules defined with the need dates as specified.

The bottom of this chart shows the proration of the hardware costs to the service kits. The proration was performed on the basis of the number of service events given in the service mission model.

S3 System Hardware Cost Prorated by Mission Type (1 of 2)

		A	B	C	D	E	F	G	H	I	J	K	L
	TOTAL SERVICE MODULE COST (1981 $M)												
INTEGRATED SYSTEM		N/A	1.4	18.9	2.2	2.9	17.4	30.4	1.0	0.2	8.5	1.0	4.9
	NUMBER USES	PRORATED SERVICE MODULE COST (1981 $K)											
DEPLOY	249		611										
SORTIE	92		226					11908	451	90	2312	451	2210
REPAIR	95		233								2388		
CHANGEOUT RECONFIGURE RESUPPLY	112		275					14527	549	110	2814	549	2690
EARTH RETURN	31		76					3990			782		
DEORBIT	8		20		304	400	17400				204		
SPIN SERVICE	50			18900	1896	2500							

S^3 System Hardware Cost Prorated by Mission Type (2 of 2)

	TOTAL SERVICE MODULE COST (1981 $M)						INTEC.	
	M	N	O	P	Q	R		
INTEGRATED SYSTEM	21.4	77.5	0.8	7.8	8.4	N/A	0.6	205.585
	PRORATED SERVICE MODULE COST (1981 $K)							ALLOCATED MISSION TOTAL
DEPLOY							2	613
SORTIE		21626					123	39397
REPAIR	8539	22325	319				106	33910
CHANGEOUT RECONFIGURE RESUPPLY	10079	26278	377				182	58430
EARTH RETURN	2782	7286	104		6710		68	21798
DEORBIT				1076	1730		66	21200
SPIN SERVICE				6724			94	30120

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PRORATED UNIT SERVICE EVENT COST

The total cost to the individual user is estimated in this chart by the mission type. The recurring costs were added to the prorated hardware, facilities and training and simulation costs. The Right hand column represent-on the average- the user cost if the S^3 supports all the missions identified in the service model.

The possibility that the Satellite Services Organization would support less than the total number of service events results in a higher user unit cost. This is discussed in charts at the end of the Cost Estimate Section.

Prorated Unit Service Event Cost

(1981 $K) S^3 PERFORMS ALL FUNCTIONAL MISSIONS

	TOTAL EVENTS 1983-1993	RECURRING	HARDWARE	FACILITIES	TRAINING AND SIMULATION	TOTALS
DEPLOY	294	84	2.3	6	0	92
SORTIE	92	3974	427	6	25	4432
REPAIR	95	4348	356	6	13	4723
CHANGEOUT RECONFIGURE RESUPPLY	112	7435	520	6	27	7988
EARTH RETURN	31	5738	701	6	81	6526
DEORBIT	8	2737	2640	6	101	5484
SPIN SERVICE	50	528	602	0	5	1135

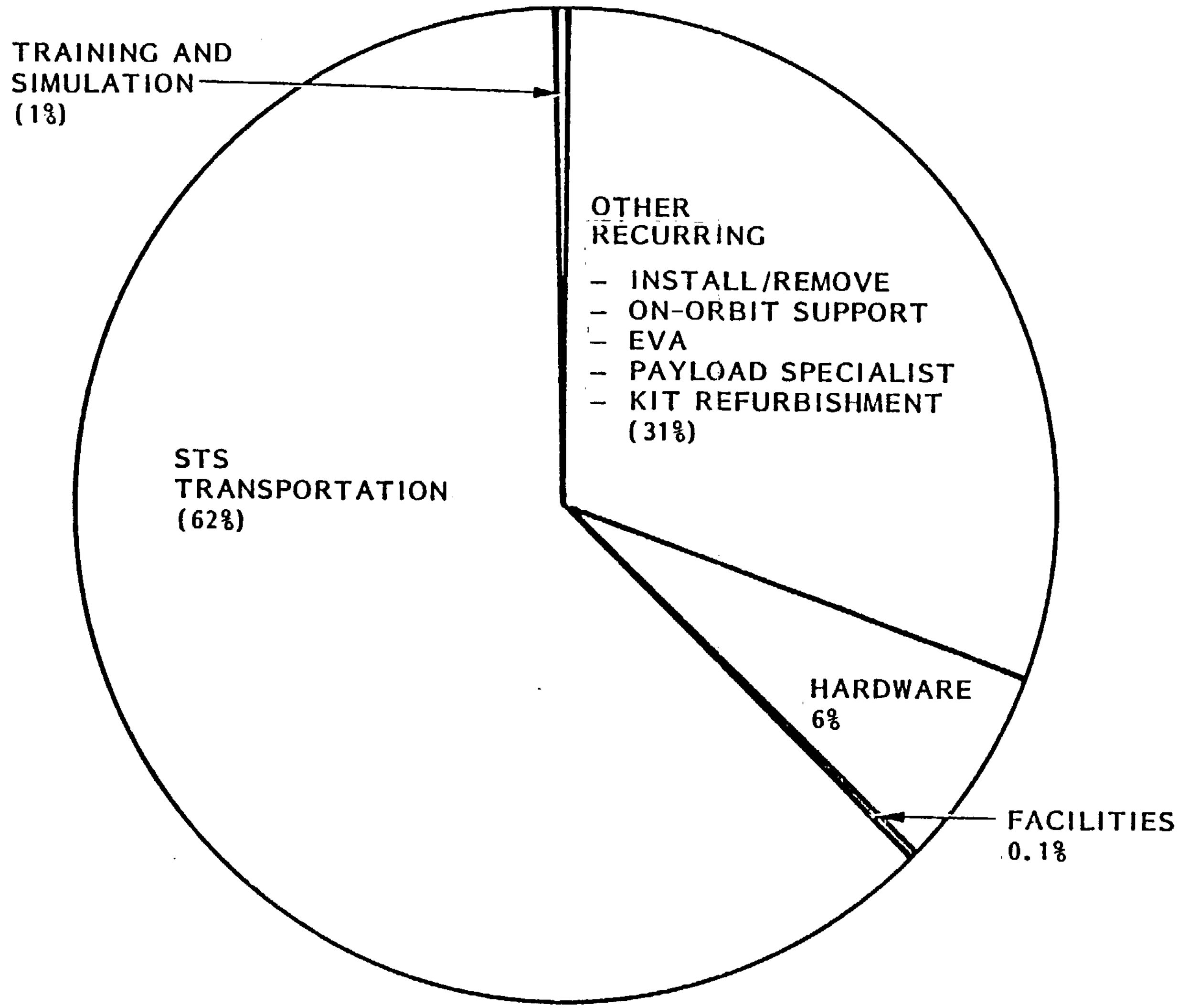
UNIT SERVICE EVENT COST BREAKDOWN

It is evident from the "Recurring Cost" estimate that the STS Transportation cost is the predominant factor in the the user unit service cost. This chart shows the percentage breakdown for the support (Changeout, Reconfigure, Resupply) class of service mission. In this chart the STS transportation cost has been broken out from the other recurring charges.

The costs to the user which are directly controllable by the Satellite Services Organization are a small fraction of the total.

Unit Service Event Cost Breakdown

PRORATED SYSTEM COST



CHANGEOUT, RECONFIGURE, RESUPPLY

NASA

Satellite Services System Cost Estimate

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- PRORATION OF FIXED COSTS
- $\boxed{\text{TOTAL PROGRAM RESOURCE REQUIREMENTS}}$

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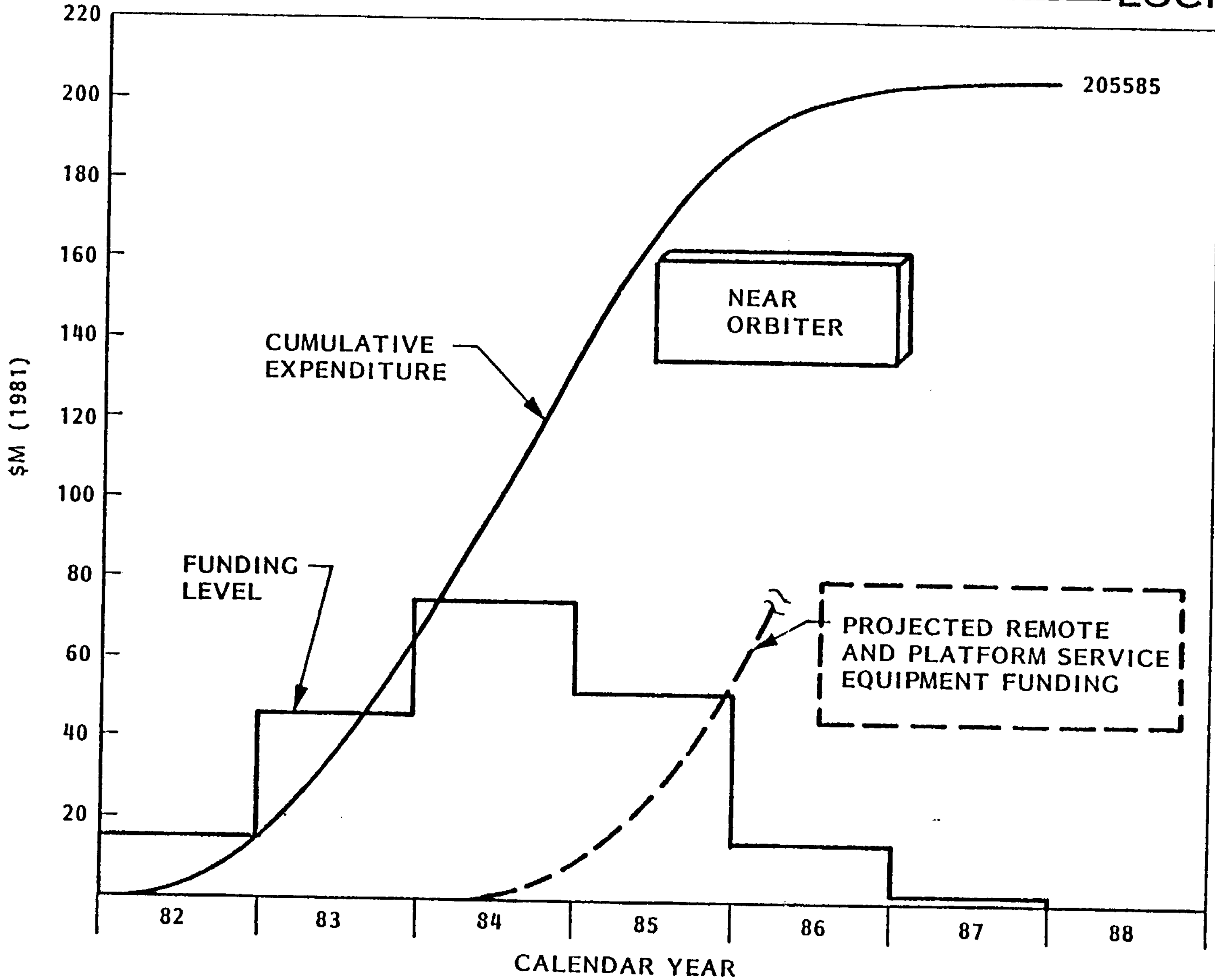
S^3 EQUIPMENT COST

This chart represents the funding required to procure the hardware to support the mission model. The year by year and cumulative funding is indicated.

For the extended capability S^3 more complex equipment is required e.g., OTV, TMS, Platform docking equipment, etc. The expenditures for these were not estimated but are also shown in dashed lines on this chart. The start date for development of the extended capability equipment depends on the projected need for these capabilities. The dates shown here are the earliest likely.

S3 Equipment Cost



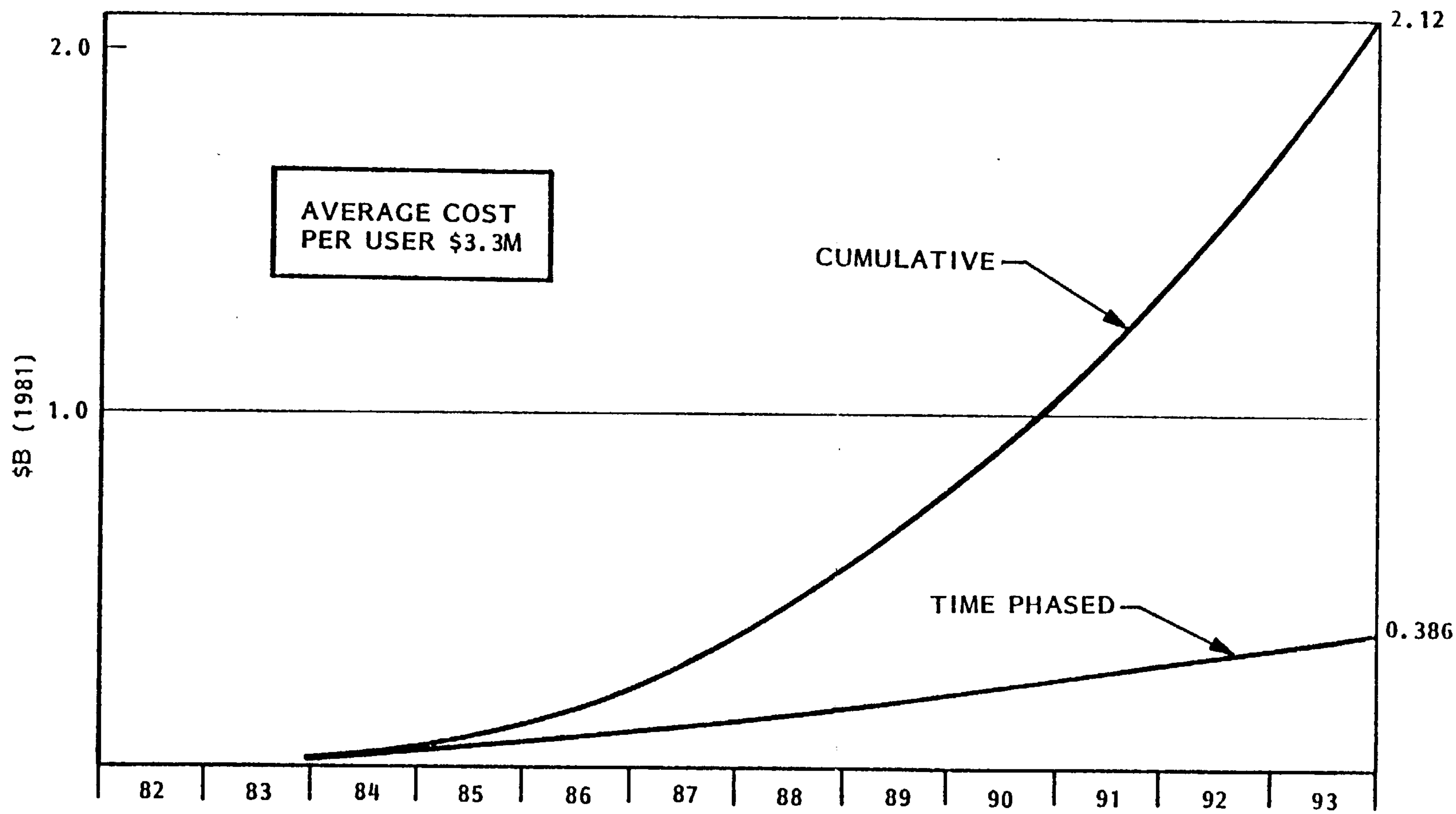
S^3 TOTAL USER EXPENDITURES

The total expenditures for Satellite Services by the user community is presented here. It is the accumulation of the unit service vent costs multipled by the number of events in the service mission model.

It is important to note that these expenditures are not NASA or DoD funding requirements but represent the projected outlay made by the entire Service System user community in the 1983-93 time frame.

S3 Total User Expenditures

POTENTIAL MARKET



S^3 HARDWARE COST SUMMARY

This chart indicates the cost of the service modules applicable to each of the generic service kits. The right hand column indicates the cost of the hardware under the condition that the generic service function is performed exclusive of all other service functions.

This presentation and that on the following chart when compared to the earlier proration charts indicate the advantages that accure to the user community if the total spectrum of service functions are performed rather than the individual.

The shaded area on the chart indicates the items that would be summed to arrive at the hardware cost to perform the CR&R and the Earth Return missions but not the others.

S^3 Hardware Cost Summary

(1981 $M)

	SERVICE MODULE								
	A	B	C	D	E	F	G	H	I
DEPLOY		1.4							
SORTIE		1.4					30.4	1.0	0.2
REPAIR		1.4							
CHANGEOUT RECONFIGURE RESUPPLY		1.4					30.4	1.0	0.2
EARTH RETURN		1.4					30.4		
DEORBIT		1.4		2.2	2.9	17.4			
SPIN SERVICE			18.9	2.2	2.9				
COMBINED MISSION									

S^3 Hardware Cost Summary (Contd)

(1981 $M)

	SERVICE MODULE									
	J	K	L	M	N	O	P	Q	R	INDIVIDUAL KIT TOTAL
DEPLOY										1.4
SORTIE	8.5	1.0	4.9		77.5					125.0
REPAIR	8.5			21.4	77.5	0.8				109.6
CHANGEOUT RECONFIGURE RESUPPLY	8.5	1.0	4.9	21.4	77.5	0.8				147.2
EARTH RETURN	8.5			21.4	77.5	0.8		8.4		140.1
DEORBIT	8.5						7.8	8.4		48.7
SPIN SERVICE							7.8			31.9
COMBINED MISSION										155.6

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UNIT SERVICE EVENT COST

SINGLE FUNCTIONAL MISSIONS

The total user cost for each of the generic mission classes is shown here for the case where that class is the only one performed by the Satellite Services System.

This chart when compared to the previous unit service event cost chart based on propration of the fixed costs provides an insight into the savings accruing to the user community if the S^3 consolidates and integrates all service functions. Since the recurring transportation costs are predominant, the overall savings on the unit user costs amount to approximately 10% for the integrated system.

Unit Service Event Cost

(1981 $K) S^3 PERFORMS SINGLE FUNCTIONAL MISSION

	TOTAL EVENTS 1983-1993	RECURRING	PRORATED BY SERVICE EVENTS		TRAINING AND SIMULATION AT 5% HARDWARE	UNIT MISSION TOTAL
			HARDWARE	FACILITIES		
DEPLOY	294	84	5.8	15	0.3	105
SORTIE	92	3974	1359	41	68	5442
REPAIR	95	4348	1154	39	58	5599
CHANGEOUT RECONFIGURE RESUPPLY	112	7435	1314	33	66	8848
EARTH RETURN	31	5738	4520	121	226	10605
DEORBIT	8	2737	6084	468	304	9593
SPIN SERVICE	50	528	638	0	32	1198

5. Conclusions

- HARDWARE
- PROGRAM PLANS
- OPERATIONS PLANS
- COST ANALYSIS
- OVERALL STUDY

Hardware Conclusions

- MANY EARLY-PHASE SERVICE MISSIONS CAN BE ACCOMPLISHED WITH SIMPLE EVA TOOLS
- FUTURE MISSIONS REQUIRE MORE COMPLEX HARDWARE
- IMMEDIATE FUTURE PRELIMINARY DESIGN CANDIDATES ARE:
  - CARGO CONTAINMENT SYSTEM TO TRANSPORT ORUs AND TOOLS INTO ORBIT; ORUs, TOOLS, DEBRIS, AND RETURNING SATELLITES TO EARTH
  - FLUID TRANSFER SYSTEM TO PERMIT RESUPPLY OF PROPELLANTS, REACTANTS, AND LIFE SUPPORT
  - ΔV SYSTEM TO PERMIT ACCESS TO HIGHER ALTITUDE AND OUT-OF-PHASE OR OUT-OF-PLANE SATELLITES
  - STANDARDIZED CHECKOUT SYSTEM FOR PERFORMINE MINIMUM SATELLITE STATUS TESTING FROM ORBITER

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Program Plan Conclusions

- LOCKHEED'S OUTLINE PROGRAM PLANS INDICATE NEED FOR CONTINUED PLANNING AT THE SYSTEM MANAGEMENT LEVEL:
  - CONTINUE DEVELOPMENT OF SATELLITE SERVICE TEAM
- IDENTIFIED NEAR-TERM IMPLEMENTATION ACTIONS
  - SURVEY CURRENT USER AGENCY NEEDS AND DESIRES
  - DETAIL PROGRAM PLAN FOR CONSOLIDATED AND INTEGRATED S^3
  - OBTAIN COOPERATION AND WORKING AGREEMENTS WITH USER AGENCIES
    - NASA CENTERS
    - DoD
    - COMMERCIAL
    - INTERNATIONAL

Program Plan Conclusions (Contd)

- LONGER-RANGE PLANNING
  - DEFINE FUNCTIONS AND RESPONSIBILITIES FOR:
    - SATELLITE SERVICES OPERATIONS CONTROL CENTER (SSOCC)
    - INTERFACE WORKING GROUPS
    - S^3 LOGISTICS ORGANIZATION
    - S^3 CREW SYSTEMS INTERFACE ORGANIZATION
    - SUPPLY/REPAIR/REFURBISHMENT DEPOTS

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Operations Plan Conclusions

- GROUND AND SPACE OPERATIONS ELEMENTS HAVE BEEN IDENTIFIED
- SATELLITE SERVICES ORGANIZATION RESPONSIBILITY FOR EACH IDENTIFIED ELEMENT IS YET TO BE DEFINED
- INTERFACES BETWEEN S^3 OPERATIONS AND OTHER OPERATIONS ORGANIZATIONS HAVE NOT BEEN DEFINED
- DETAILED DEVELOPMENT, GROUND AND FLIGHT OPERATIONS PLANS DEPEND ON ANSWERS TO THE FOREGOING DEFINITIONS

NASA LOCKHEED

Cost Analysis Conclusions

- EARLY TIME FRAME RESOURCE COMMITMENTS ARE MODERATE

  '82 $15 M

  '83 $47 M

  '84 $74 M

  TOTAL THROUGH 1987 = $205.5 M

- LATE TIME FRAME REQUIRES MORE SUBSTANTIAL OUTLAYS FOR LARGE SPACE STRUCTURES AND REMOTE SATELLITE SERVICE

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Cost Analysis Conclusions (Contd)

- USER CHARGE FOR HARDWARE IS 2 TO 3 TIMES HIGHER FOR SINGLE GENERIC MISSION APPROACH THAN FOR INTEGRATED TOTAL SYSTEM APPROACH
  - TOTAL USER SERVICE EVENT COST IS 10% TO 12% HIGHER WHEN STS CHARGES ARE INCLUDED
- PROVIDING FOR DEPLOYMENT SERVICE IS MOST COST EFFECTIVE
  - 0.3% OF EQUIPMENT COST
  - 1.3% OF USER COST
  - 41% OF SERVICE EVENTS

Cost Analysis Conclusions (Contd)

- DEORBIT IS LIKELY LEAST COST EFFECTIVE
  - 10% OF EQUIPMENT COST
  - 2% OF TOTAL USER COST
  - 1% OF SERVICE EVENTS
- THE MOST USEFUL "CHANGEOUT, RECONFIGURE RESUPPLY" CLASS ACCOUNTS FOR
  - 28% OF THE EQUIPMENT COST
  - 45% OF TOTAL USER COST
  - 18% OF SERVICE EVENTS

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Principal Conclusions

- THE VERSATILITY OF MAN-IN-SPACE CAN BEST BE AUGMENTED BY PROVIDING THE ASTRONAUTS WITH SIMPLE TOOLS AND AIDS THAT FACILITATE A WIDE VARIETY OF SERVICE FUNCTIONS TO BE PERFORMED BY EVA
  - THIS APPROACH LENDS ITSELF TO EARLY IMPLEMENTATION AT MINIMUM COST
  - MUCH OF THE EQUIPMENT NEEDED FOR IMMEDIATE FUTURE SERVICING EXISTS TODAY

Principal Conclusions (Contd)

- MODULAR SERVICE EQUIPMENT DESIGNED FOR MULTI-MISSION APPLICATION CAN ACCOMPLISH ALL IDENTIFIED NEAR-ORBITER SERVICE FUNCTIONS
  - THIS BASELINE EQUIPMENT COMPLEMENT FORMS THE BASIS FOR EXTENDED HEO/GEO SERVICING
- SERVICE EXTENSION TO HEO/GEO REQUIRES OTV DEVELOPMENT
- EARLY IMPLEMENTATION CAN BE ACCOMPLISHED AT MODERATE FUNDING LEVELS FOR SERVICE EQUIPMENT
  - ORGANIZATION OF INTERFACE WORKING GROUPS

1982 $15 M

1983 $47 M

1984 $74 M

TOTAL THROUGH 1987 = $205 M

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- TASK 1: MISSION REQUIREMENTS AND ECONOMIC ANALYSIS
  - CONDUCT AN ANALYSIS TO ESTABLISH THE BENEFITS TO THE USERS OF ON-ORBIT SERVICING
- TASK 2: CARGO CONTAINMENT SYSTEM DEFINITION
  - PERFORM A PRELIMINARY DESIGN AND PRODUCE A TOP LEVEL SPECIFICATION FOR THE CONTAINMENT OF SPACE OBJECTS THAT WERE NOT DESIGNED FOR EARTH RETURN IN THE ORBITER

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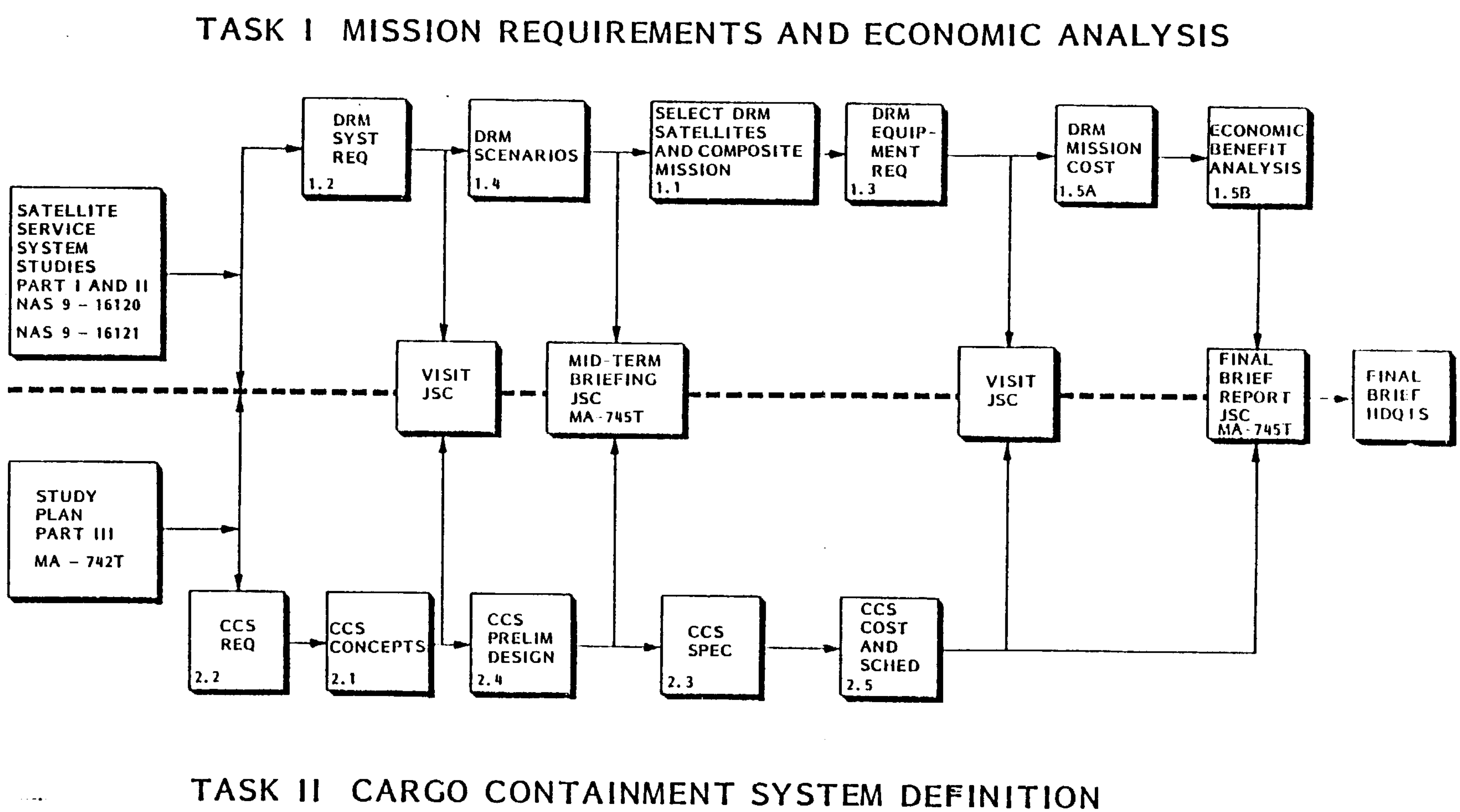
Part III Study Logic Flow



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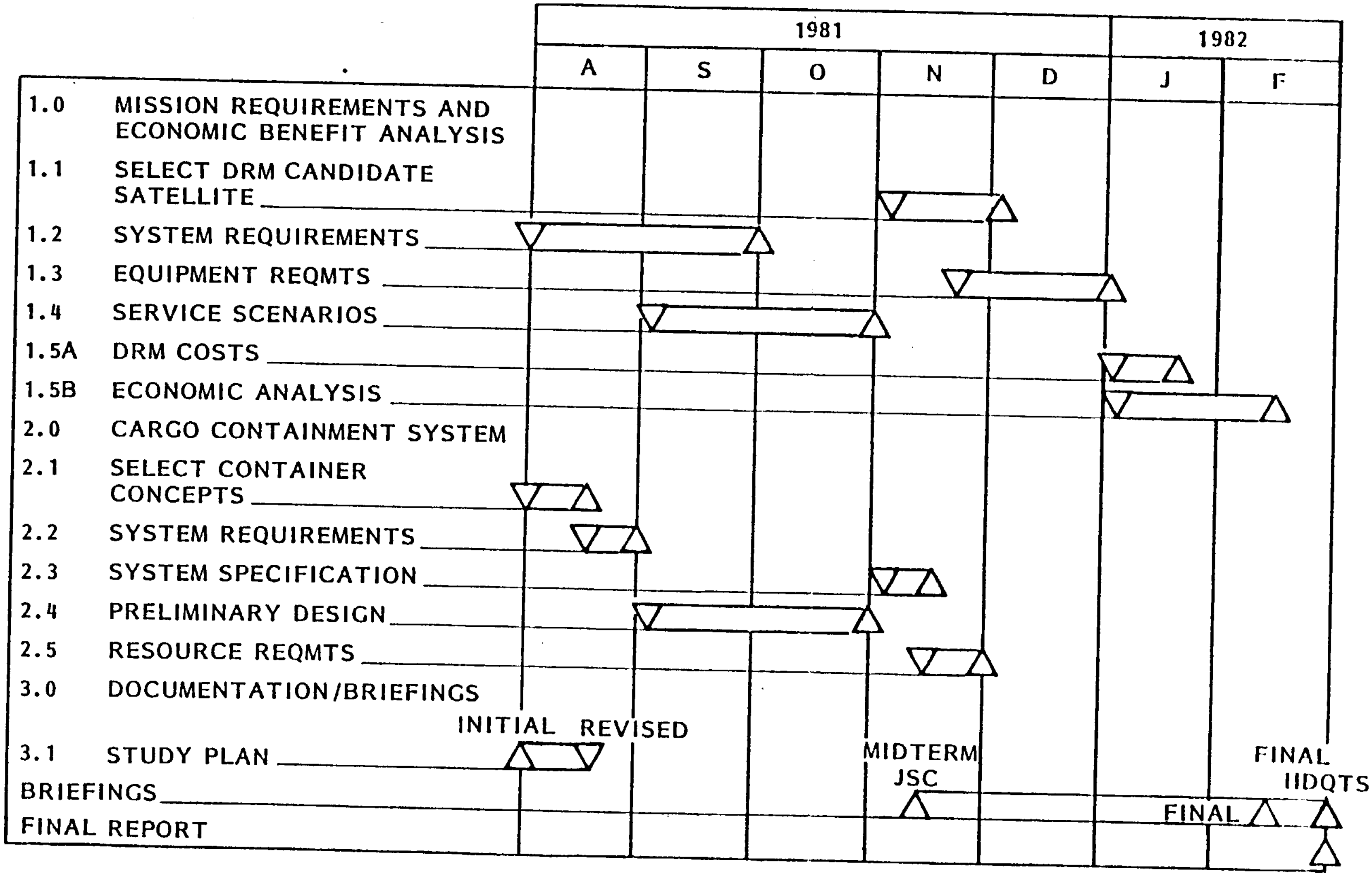
STUDY SCHEDULE



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